FIRST LINES OF SCIENCE;

OR,

A COMPREHENSIVE AND PROGRESSIVE

VIEW

OF THE LEADING BRANCHES OF

MODERN SCIENTIFIC DISCOVERY

AND

INVENTION.

WITH NUMEROUS ENGRAVINGS.

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INTRODUCTION.

THE term science is derived from the Latin *scientia*, a word which, in its most general acceptation, signifies *knowledge*. In this sense it embraces an acquaintance with every object which the boundless field of creation presents to the contemplation of man.

But it is obvious, that in a work like the present, the briefest abridgement of the circle of the sciences is an impossibility; and therefore our attention must be confined chiefly to those particular branches of scientific pursuit to which the present highly improved state of things, in a manner, compels us to give the preference.

Guided by this consideration in our selection, we hope to avoid the charge of undervaluing any of the numerous and widely extended branches of the tree of knowledge; for while every species of knowledge which can be acquired by the exertion of the human faculties must be allowed its relative importance, as forming a part of the grand whole, yet, where selection becomes indispensable, *utility* ought to decide.

But even on this ground the Editor may be thought to have neglected some of the essential parts of a course of scientific instruction. Arithmetic, Algebra, and the higher branches of the Mathematics, it will be said, form the basis of all acquirements which assume the lofty name of science. This is certainly most true; and it may be sufficient to observe in reply, that throughout the following work it is taken for granted that the reader has previously made himself acquainted with the two former, and that he possesses such a share of knowledge of the latter as will enable him readily to enter into the investigation of any subject requiring such aid.

At the same time, to render the work as extensively useful as possible, as much elementary matter will be found blended with the discussion of the various topics introduced as is consistent with the requisite brevity.

The Editor would here also observe, that he is well aware how intimately connected the study of all natural science is with that most important of all sciences, the science of Theology. He is decidedly of opinion that the astonishing changes now taking place in the intellectual condition of mankind can be attributed to no other cause than a remarkable out-pouring of the spirit of wisdom from the great fountain of intelligence; and that the result of it will be, however near or however remote such an event may be, the spiritual improvement of the human race. At present we see but the dawning of the day; but as certainly as the day has dawned may we expect its meridian splendour. To all, as an intelligent writer has observed, from the infant to the man, and from the peasant to the prince, the flood-gates of knowledge are set open; and the nations rush eagerly to imbibe the mind-informing streams. It would afford the Editor inexpressible delight to trace the connexion between the present diffusion of scientific knowledge, and the remarkable phenomenon of the circulation of that VOLUME, whose province it is to draw aside the veil which separates between the *spiritual*, or world of *causes*, and the *natural*, or world of *effects*. This he conceives to be, in the proper sense of the term, a *desideratum*, which, if the present effort should meet the approbation of the public, he may afterwards attempt to supply.

In the mean time he must content himself with briefly remarking that this connexion, although hitherto but little attended to by the generality of writers on scientific subjects, begins to force itself upon the attention of those whose talents and office have given them an extensive influence over the population of Great Britain. Surely it forms not the least striking feature in the signs of the times to read in a work, which professes to speak in the highest tone assumed by our national church, such language as the following:—" It is now too late to press objections, be they strong or weak, against universal education, against that (if we may speak chemically) hyperoxygenated passion for imparting knowledge, which is so prevalent in our times. We are not left to argue or debate upon what might have been better or worse; we must act upon what we find in operation. The fountains of the great deep have been broken up, and a deluge of information,—theological, scientific, and civil,—is carrying all before it, filling up the valleys, and scaling the mountain tops. A spirit of inquiry has gone forth, and sits brooding on the mind of man. The effect may be good, or it may be bad; much will depend on right regulation and direction. Let the objectors to general education tell us it is a fierce forerunner of anarchy, insubordination, and infidelity,—a whirlwind whose desolating effects we shall live to rue. In reply we would say, Be it what they please; it is for the clergy of the National Church to ride that whirlwind, and direct the storm; to moderate and guide its force, that, like every other *apparent* evil permitted by Providence, it may conduce to some good end."

It is hoped the order adopted in the following sheets will be found peculiarly suited to promote the main design of the work, which is to lead the mind of the reader by a natural and easy gradation from the humbler to the more elevated departments of science.

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SCIENTIFIC DISCOVERIES

AND

INVENTIONS.

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CHAPTER I.

GEOGRAPHY.

GEOGRAPHY, in the usual acceptation of the word, is that science which describes the *surface* of the earth; the term is derived from the two Greek words γη or γεα *the earth*, and γραφω *I write*.

What is called general geography embraces a wide view of the subject; regarding the earth astronomically as a planet, the grand divisions of land and water, the winds, tides, meteorology, and may extend to what is called mechanical geography, including directions for the construction of globes, maps, and charts. The study of geography being of so much practical importance in life, must have commenced in the early ages of the world. It was regarded as a science by the Babylonians and Egyptians, from whom it passed to the Greeks, and from these to the Romans, the Arabians, and the western nations of Europe. Thales of Miletus, in the sixth century before Christ, first made observations on the apparent progress of the sun from tropic to tropic; and is said to have written two treatises, the one on the tropic, and the other on the equinox, whence he was led to the discovery of the four seasons, which are determined by the equinoxes and solstices. We are assured this knowledge was obtained by means of the gnomon. Thales, it is also said, constructed a globe, and represented the land and sea upon a table of brass.

Maps at first were little more than rude outlines, and topographical sketches of different countries. The earliest on record were those of Sesostris, mentioned by Eustathius, who says that "this Egyptian king, having traversed great part of the earth, recorded his march in maps, and gave copies of them not only to the Egyptians, but to the Scythians, to their great astonishment." Some have imagined, with much probability, that the Jews made a map of the Holy Land, when they gave the different portions to the nine tribes at Shiloh; for Joshua tells us that they were sent to walk through the land, and that they described it in seven parts of a book; and Josephus relates that when Joshua sent out people from the different tribes to measure the land, he gave them as companions persons well skilled in geometry, who could not be mistaken in the truth.

The first Grecian map on record was that of Anaximander, mentioned by Strabo, supposed to be that referred to by Hipparchus under the designation of the ancient map.

Eratosthenes first attempted to reduce geography to a regular system, and introduced a regular parallel of latitude, which began at the straits of Gibraltar, passed eastward through the isle of Rhodes, and so on to the mountains of India, noting all the intermediate places through which it passed. In drawing this line, he was not regulated by the same latitude, but by observing where the longest day was 14 hours and a half, which Hipparchus afterwards determined was the latitude of 36 degrees.

This first parallel through Rhodes was ever after considered with a degree of preference, in constructing all the ancient maps; and the longitude of the then known world was often attempted to be measured in stadia and miles, according to the extent of that line, by many succeeding geographers.

Though the maps of Eratosthenes were the best of his time, they were yet very imperfect and inaccurate. They contained little more than the states of Greece, and the dominions of the successors of Alexander, digested according to the surveys above mentioned. He had indeed seen, and has quoted, the voyages of Pythias into the great Atlantic ocean, which gave him some faint ideas of the western parts of Europe; but so imperfect, that they could not be realized into the outlines of a chart. Strabo says he was very ignorant of Gaul, Spain, Germany, and Britain; and he was equally ignorant of Italy, the coast of the Adriatic, Pontus, and all the countries towards the north.

Such was the state of geography, and the nature of the maps, before the time of Hipparchus. He made a closer connexion between geography and astronomy, by determining the latitudes and longitudes from celestial observations.

The Roman empire had been enlarged to its greatest extent, and all its provinces well known and surveyed, when Ptolemy, about 150 years after Christ, composed his system of geography. The chief materials he employed in composing this work were the proportions of the gnomon to its shadow, taken by different astronomers at the times of the equinoxes and solstices; calculations founded on the length of the longest days; the measured or computed distances of the principal roads contained in their surveys and itineraries; and the various reports of travellers and navigators. All these were compared together, and digested into one uniform body or system; and afterwards were translated by him into a new mathematical language, expressing the different degrees of latitude and longitude, after the invention of Hipparchus, which had been neglected for 250 years.

Ptolemy's system of geography, notwithstanding it was still very imperfect, continued in vogue till the last three or four centuries, within which time the great improvements in astronomy, the many discoveries of new countries by voyagers, and the progress of war and arms, have contributed to bring it to a very considerable degree of perfection.

GENERAL PRINCIPLES OF GEOGRAPHY.

The general principles of geography are, the spherical figure of the earth; its rotation on its axis; its revolution round the sun; and the position of the axis or line round which it revolves with regard to the celestial luminaries. That the earth and sea taken together constitute one vast sphere is demonstrable by the following arguments: 1. To people at sea the land disappears, though near enough to be visible, were it not for the intervening convexity of the water. 2. The higher the eye is, the more extensive is the prospect; whence it is common for sailors to climb up to the tops of the masts to discover land or ships at a distance. 3. To people on shore, the mast of a ship at sea appears before the hull; but were the earth an even plane, not the highest objects, but the largest, would be longest visible. 4. The convexity of any piece of still water of a mile or two in extent may be perceived by the eye. A little boat, for instance, may be perceived by a man who is any height above the water; but if he stoops down or lays his eye near the surface, he will find that the fluid appears to rise and intercept the view of the boat entirely. 5. The earth has been often sailed round, as by Magellan, Drake, Dampier, Anson, Cook, and many other navigators, which demonstrates that the surface of the ocean is spherical.

A great many of the terrestrial phenomena depend upon the globular figure of the earth, and the position of its axis with regard to the sun, particularly the rising and setting of the celestial luminaries, the length of the days and nights, &c.

Though the sun rises and sets all over the world, the circumstances of his doing so are very different in different countries. The most remarkable of these circumstances is the duration of the light, not only of the sun himself, but of the twilight before he rises and after he sets. In the equatorial regions, darkness comes on very soon after sunset. In our climate the twilight always continues about two hours, and during the summer season it continues in a considerable degree during the whole night. In countries farther to the northward or southward, the twilight becomes brighter and brighter as we approach the poles, until at last the sun does not appear to touch the horizon, but goes in a circle at some distance above it for many days successively. In like manner, during the winter, the same luminary sinks lower and lower, until at last he does not appear at all; and there is only a dim twinkling of twilight for an hour or two in the middle of the day. By reason of the refraction of the atmosphere, however, the time of darkness, even in the most inhospitable climates, is always less than that of light. In the warmer climates the sun has often a beautiful appearance at rising and setting, from the refraction of his light through the vapours which are copiously raised in those parts. In the colder regions, halos, parhelia, aurora borealis, and other meteors, are frequent; the two former owing to the great quantity of vapour continually flying from the warm regions of the equator to the colder ones of the poles. In the high northern latitudes, thunder and lightning are unknown, or but seldom heard of; but the more terrible phenomena of earthquakes, volcanos, &c. are by no means unfrequent. These, however, seem chiefly to affect islands and the maritime parts of the continent.

Were the earth a perfect plane, the sun would appear to be vertical in every part of it; for, in comparison with the immense magnitude of that luminary, the diameter of this globe itself is but very small; and as the sun, were he near to us, would do much more than cover the whole earth, so, though he were removed to any distance, the whole diameter of the latter would make no difference in the apparent angle of altitude. By means of the globular figure of the earth also, together with the great disparity between the diameters of the two bodies, some advantage is given to the day over the night; for thus the sun, being immensely the larger of the two, shines upon more than one half of the earth; whence the unenlightened part has a shorter way to go before it again receives the benefit of his rays. This difference is greater in the inferior planets, Venus and Mercury, than in the earth.

To the globular figure of the earth likewise is owing the long moonlight which the inhabitants of the polar regions enjoy. The same thing likewise occasions the appearance and disappearance of certain stars at some seasons of the year in some countries; for, were the earth flat, they would all be visible in every part of the world at the same time.

In geography the circles which the sun apparently describes in the heavens are supposed to be extended as far as the earth, and marked on its surface; and in like manner we may imagine as many circles as we please to be described on the earth, and their planes to be extended to the celestial sphere, till they mark concentric ones on the heavens. The most remarkable of those supposed by geographers to be described in this manner are the following:

1. The horizon. This is probably a double circle, one of the horizons being called the sensible, and the other the rational. The former comprehends only that space which we can see around us upon any part of the earth, and which is very different according to the difference of our situation. The other, called the rational, is a circle parallel to the former, and passing through the centre of the earth, supposed to be continued as far as the celestial sphere itself. To the eyes of the spectators there is always a vast difference between the sensible and rational horizons; but from the immense disparity betwixt the size of the earth and celestial sphere, planes of both circles may be considered as coincident. Hence in geography, when the horizon, or plane of the horizon, is spoken of, the rational is always understood when nothing is said to the contrary. In consequence of the round figure of the earth, every part has a different horizon. The poles of the horizon, that is, the points directly above the head, and opposite to the feet of the observer, are called the zenith and nadir.

2. A great circle described upon the sphere of the heaven, and passing through the two vertical points,

is called a vertical circle, or an azimuth; and of these we may suppose as many as we please all round the horizon. In geography every circle obtains the epithet of great, whose plane passes through the centre of the earth; in other cases they are called lesser circles.

3. Almacantars are circles supposed to be drawn upon the sphere parallel to the horizon, and grow less and less as they approach the vertical points, where they entirely vanish.

The apparent distances between any two celestial bodies are measured by supposing arches of great circles drawn through them, and then finding how many degrees, minutes, &c. of these circles are intercepted between them.

4. Sometimes the visible horizon is considered only with regard to the objects which are upon the earth itself, in which case we may define it to be a lesser circle on the surface of the earth, comprehending all such objects as are at once visible to us; and the higher the eye, the more is the visible horizon extended. It is most accurately observed, however, on the sea, on account of the absence of those inequalities which at land render the circle irregular.

5. The equator is a great circle upon the earth, every part of which is equally distant from the poles or extremities of the imaginary line on which the earth revolves. In sea-language, it is usually called the line.

6. The meridian of any place is a great circle on the earth drawn through that place and both poles of the earth. It cuts the horizon at right angles, marking upon it the true north and south points; dividing also the globe into two hemispheres, called the eastern and western, from their relative situation to that place and to one another. The poles divide the meridians into two semicircles, one of which is drawn through the place to which the meridian belongs, the other through that point of the earth which is opposite to the place. By the meridian of a place, geographers and astronomers often mean that semicircle which passes through the place, and which may therefore be called the geographical meridian. All places being under this semicircle are said to have the same meridian; the semicircle opposite to this is called the opposite

meridian. The meridians are thus immoveably fixed to the earth as much as the places themselves on its surface, and are carried along with it in its diurnal rotation. When the geographical meridian of any place is, by the rotation of the earth, brought to point at the sun, it is noon or mid-day at that place. The rotation of the earth is from west to east; whence the celestial bodies appear to move the contrary way. East and west, however, are terms merely relative, since a place may be west from one part of the earth, and east from another; but the true east and west points from any place are those where its horizon cuts the equator.

7. All places lying under the same meridian are said to have the same longitude, and those which lie under different meridians to have different longitudes; the difference of longitude being reckoned eastward or westward on the equator. Thus, if the meridian of any place cuts the equator in a point 15 degrees distant from another, we say there is a difference of 15° longitude betwixt these two places. Geographers usually fix upon the meridian of some remarkable place for the first meridian, and reckon the longitude of all others by the distance of their meridians from that which they have determined upon as the first; measuring sometimes eastward on the equator all around the globe, or sometimes only half east and the other west; according to which last measurement no place can have more than 180° longitude either east or west. By the British geographers the royal observatory at Greenwich is accounted the place of the first meridian.

8. If we suppose 12 great circles, one of which is the meridian to a given place, to intersect each other at the poles of the earth, and divide the equator into 24 equal parts, these are the hour-circles of that place. These are by the poles divided into 24 semicircles, corresponding to the 24 hours of the day and night. The distance betwixt each two of these semicircles is 15°, being the 24th part of 360; and by the rotation of the earth each succeeding semicircle points at the sun one hour after the preceding; so that in 24 hours all the semicircles point successively at the sun.

Hence it appears, that such as have their meridian 15° east from any other have likewise noon one hour sooner, and the contrary: and in like manner every other hour of the natural day is an hour sooner at the one place than at the other. Hence, from any instantaneous appearance in the heavens observed at two distant places, the difference of longitude may be found, if the hour of the day is known at each place. Hence, also, were a man to travel or sail round the earth from west to east, he would reckon one day more to have passed than they do who stay at the place whence he set out; so that their Monday would be his Tuesday, &c.

9. The equator divides the earth into two hemispheres, called the northern and southern: all places lying under the equator are said to have no latitude; and all others to have north or south latitude according to their situation with respect to the equator. The latitude itself is the distance from the equator measured upon the meridian, in degrees, minutes, and seconds. The complement of latitude is the difference between the latitude itself and 90°, or as much as the place itself is distant from the pole; and this complement is always equal to the elevation of the equator above the horizon of the place. An inhabitant of the earth at either of the poles would have always one of the celestial poles in his zenith, and the other in his nadir, the equator coinciding with the horizon.

Those who live under the equator have both poles in the horizon, all the celestial parallels cutting the horizon at right angles. Lastly, those who live between either of the poles and the equator are said to live in an oblique sphere, or to have an oblique horizon, because the celestial equator cuts their horizon obliquely, and all the parallels in the celestial sphere have their planes oblique to that of the horizon.

By the arctic and antarctic circles, however, modern geographers understand two fixed circles at the distance of 23½ degrees from the pole. These are supposed to be described by the poles of the ecliptic, and mark out the space all round the globe where the sun appears to touch the horizon at midnight in the summer time, and to be entirely sunk below it in the winter. These are also called the polar circles.

According to the different positions of the globe with regard to the sun, the celestial bodies will exhibit different phenomena to the inhabitants. Thus, in a parallel sphere, they will appear to move in circles round the horizon; in a right sphere they would appear to rise and set as at present, but always in circles, cutting the horizon at right angles; but in an oblique sphere the angle varies according to the degree of obliquity, and the position of the axis of the sphere with regard to the sun. Hence we easily perceive the reason of the sun's continual change of place in the heavens; but though it is certain that this change takes place every moment, the vast distance of the luminary renders it imperceptible for some time, unless to very nice astronomical observers. Twice a year he is on the equator, and then the days and nights are nearly equal all over the earth. This happens in the months of March and September; after which the sun proceeding either northward or south, according to the season of the year, and the position of the observer, the days become longer or shorter than the nights, and summer or winter comes on. The recession of the sun from the equator, either northward or southward, is called his declination, and is either north or south according to the season of the year; and when this declination is at its greatest height, he is then said to be in the tropic, because he begins to turn back (the word tropic being derived from the Greek *τρεπω, I turn*). The space between the two tropics, called the torrid zone, extends 47 degrees of latitude all round the globe; and throughout the whole of that space the sun is vertical to some of the inhabitants twice a year, but to those who live directly under the tropics only once. Throughout the whole torrid zone also there is little difference between the length of the days and nights.

From an observation of the diversity in the length of the days and nights, the rising and setting of the sun, with the other phenomena already mentioned, geographers divide the surface of the earth into certain districts, which they call climates. This method of dividing the surface of the earth into climates is not of real practical utility, since it does not furnish any certain criterion for judging of the climate in a meteorological point of view.

From the various appearances of the sun, and the effects of his light and heat upon different parts of the earth, the division of it into zones has arisen. These are five in number. 1. The torrid zone, lying between the two tropics for the space of 47° of latitude. This is divided into two equal parts by the equator. 2. The two temperate zones lie between the polar circles and the tropics, containing a space of 43° of latitude. And, 3. The two frigid zones lie between the polar circles and the poles. In these last the longest day is never below twenty-four hours; in the temperate zones it is never quite so much; and in the torrid zones it is never above 14. The zones are named from the degree of heat they were supposed to be subjected to. The torrid zone was supposed by the ancients to be uninhabitable, on account of its heat; but this is now found to be a mistake, and many parts of the temperate zones are warmer than the torrid zone itself. Towards the polar circles also these zones are extremely cold during the winter season. Only a small part of the northern frigid zone, and none of the southern, is inhabited. Some geographers reckoned six zones, dividing the torrid zone into two by the equator.

Besides these there are other terms belonging to geography which it is necessary to explain.

A *continent* is a large portion of the earth, which comprehends several countries that are not separated by any sea; such are Europe, Asia, Africa, and America. An *island* is a part of the earth entirely surrounded by water; as Great Britain. A *peninsula* is a tract of land almost surrounded with water, and is joined to a continent only by a narrow neck; such is the Morea in Greece. An *isthmus*, or neck of land, is that part by which a peninsula is joined to a continent, or two continents together; as the isthmus of Suez, which joins Africa to Asia. A *promontory*, or cape, is a high part of land which stretches into the sea; thus the Cape of Good Hope is a promontory. An *ocean* is a vast collection of waters surrounding a considerable part of the continent; as the Atlantic. A *sea* is a smaller collection of waters; as the Black Sea. A *gulf* is a part of the sea which is nearly surrounded with land; as the Gulf of Venice. A *bay* has a wider entrance than a gulf; as the Bay of Biscay. A *strait* is a narrow passage that joins two seas; as the Strait of Gibraltar, which joins the Mediterranean to the Atlantic. A *lake* is a large collection of water entirely surrounded by land, having no visible communication with the sea; as the Caspian in Asia. A *river* is a stream of water that has its source from a spring, which keeps constantly running till it falls into some other river, or into the sea.

The ancients considered the globe under the three grand divisions of Asia, Europe, and Africa. Modern discoveries have added a fourth division, that of America, which, exceeding even Asia in size, might have been admitted under two grand and distinct denominations, limited by the isthmus of Darien. The vast extent of New Holland, which seems too large to be ranked among islands, and too small for a continent, eludes the petty distinctions of man; and geographers hesitate whether to ascribe it to Asia, or to denominate it a fifth specific division of the earth.

Of the grand divisions of the earth, Asia has ever been esteemed the most populous; and is supposed to contain five hundred millions of souls. The population of Africa may be estimated at thirty millions, of America at twenty millions, and two hundred millions may perhaps be assigned to Europe.

The natural division of the surface of the globe is into sea and land; about three-fourths of the whole being occupied by water. The remaining fourth consists of lands, elevated more or less above the level of the sea, interspersed, in some parts, with smaller collections of water at various heights, and in a few instances, somewhat lower than the general surface of the main ocean. Thus the Caspian Sea is said to be about three hundred feet lower than the ocean.

The great continent, composed of Europe, Asia, and Africa, constitutes about a seventh of the whole face of the earth; America about a sixteenth; and Australasia, or New South Wales, about a fiftieth: or in hundredth parts of the whole, Europe contains two; Asia, seven; Africa, six; America, six; and Australasia, two; the remaining seventy-seven being sea; although some authors assign seventy-two parts only out of one hundred to the sea, and twenty-eight to the land.

The general inclinations and levels of the continents are discovered by the course of their rivers. Of these the principal are, the Amazons, the Senegal, the Nile, the river St. Lawrence, the Hoangho, the river La Plata, the Yenisei, the Mississippi, the Volga, the Oby, the Amur, the Oronooko, the Ganges, the Euphrates, the Danube, the Don, the Indus, the Dnieper, and the Dwina; and this is nearly the order of their magnitudes. But if we class them according to the length of country through which they run, the order will, according to Major Rennel's calculation, be somewhat different; taking the length of the Thames for unity, he estimates that of the river of Amazons at 15¾; the Kian Kew, in China, 15½; the Hoangho, 13½; the Nile, 12½; the Lena, 11½; the Amur, 11; the Oby, 10½; the Yenisei, 10; the Ganges, its companion the Burrampooter, the river of Ava, and the Volga, each 9½; the Euphrates, 8½; the Mississippi, 8; the Danube 7; the Indus, 5½; and the Rhine 5¼.

The grandest concavity of this globe is filled by the Pacific Ocean; occupying nearly half its surface from the eastern shores of New Holland, to the western coast of America, and diversified with several groups of islands, which seem in a manner the summits of vast mountains emerging from the waves. This ocean receives but few rivers, the chief being the Amur from Tartary, the Hoan Ho and Kian Kew from China, while the principal rivers of America run towards the east.

Next to this in magnitude is the Atlantic, between the old and new continents; and the third is the Indian ocean. The seas between the arctic and antarctic circles and the poles have been sometimes styled the Arctic and Antarctic Oceans; but the latter is only a continuation of the Pacific, Atlantic, and Indian Oceans; while the Arctic Sea is partly embraced by continents, and receives many important rivers. Besides these, there are other seas more minute, as the Mediterranean, the Baltic, and others still smaller, till we come by due gradation to inland lakes of fresh water.

The courses of rivers are sometimes marked by oblong concavities, which generally at first intersect the higher grounds, till the declivity becomes more gentle on their approach towards their inferior receptacles. But even large rivers are found sometimes to spring from lowland marshes, and wind through vast plains, unaccompanied by any concavity, except that of their immediate course; while on the other hand, extensive vales, and low hollow spaces, frequently occur destitute of any stream. Rivers will also sometimes force a passage where nature has erected mountains and rocks against it, and where the concavity would appear to be in another direction, which the river might have gained with more ease. In like manner, though the chief mountains of Europe extend in a south-easterly and north-westerly direction, yet there are so many exceptions, and such numerous and important variations in other parts of the globe, as to render any attempt at a general theory vain.

From the vast expanse of oceanic waters, arises in the ancient hemisphere that wide continent, which contains Asia, Europe, and Africa; and in the modern hemisphere the continent of America, which forms a kind of separate island, divided by a strait of the sea from the ancient continent. But the grandest division of the ancient continent is Asia, the parent of nations, and of civilization: on the north-east and south, surrounded by the ocean; but on the west, divided by an ideal line from Africa; and from Europe by boundaries not very strongly impressed by the hand of nature. The Russian and the Turkish empires, extending over large portions of both continents, intimately connect Asia with Europe. But for the sake of clearness and precision, geographers retain the strict division of the ancient continent into three parts, which if not strictly natural, is ethical, as the manners of the Asiatic subjects of Russia, and even of Turkey, differ considerably from those of the European inhabitants of those empires.

In this short sketch we have said little respecting the inhabitants of the earth. To enter on their customs, manners, habits, manufactures, religions, &c. would far exceed our limits; we shall therefore close this part of the subject of geography, with an extract from a well written and interesting work, Dick's Christian Philosopher, respecting the number of the inhabitants of the globe.

The number of inhabitants, says this author, which people the earth at one time, may be estimated to amount to at least *eight hundred millions;* of which 500,000,000 may be assigned to Asia; 80,000,000 to Africa; 70,000,000 to America, and 150,000,000 to Europe. With regard to their religion they may be estimated as follows:

Pagans	490,000,000
Mahometans	130,000,000
Roman Catholics	100,000,000
Protestants	43,000,000
Greeks and Armenians	30,000,000
Jews	7,000,000
	800,000,000

If we suppose that the earth, at an average, has always been as populous as it is now, and that it contains 800,000,000 of inhabitants, and if we reckon thirty-two years for a generation, at the end of which period the whole human race is renewed—it will follow that 145,000,000,000 of human beings have existed on the earth since the present system of our globe commenced, reckoning 5,827 years from Adam to the present time: and, consequently, if mankind had never died, there would have been 182 times the present number of the earth's inhabitants now in existence.

It follows from this statement, that 25,000,000 of mankind die every year, 2,853 every hour, and forty-seven every minute, and that, at least, an equal number during these periods, is emerging from nonexistence to the stage of life; so that, almost every moment, a rational and immortal being is ushered into the world, and another is transported into the invisible state. Whether, therefore, we contemplate the world of matter, or the world of mind, we perceive incessant changes and revolutions going on which are gradually carrying forward the earth and its inhabitants to some important consummation.—If, continues this author, we suppose, that, before the close of time, as many human beings will be brought into existence as have already existed, during the by-past ages of the world, there will of course be found at the general resurrection 290,000,000,000 of mankind. Vast as such an assemblage would be, the whole of the human beings here supposed, allowing six square feet for every individual, could be assembled within the space of 62,400 square miles, or, on a tract of land not much larger than that of England, which contains, according to the most accurate calculation, above 50,000 square miles.

On the above it may be necessary to remark that the intelligent author seems to entertain the common opinion that this globe will at some future period be destroyed by fire; and in support of this opinion he quotes some passages of Scripture which seem, when taken literally, to favour the idea, but which on examination will be found to afford no ground whatever for such an idea. It is rather surprising that the author should not himself see the inconclusiveness of his own reasoning. He is well aware that the spiritual world is the receptacle of the inhabitants of this earth when they leave it;—he knows also, or at least he *has no doubt* on the subject, that there are myriads of worlds besides ours in the universe, peopled with human beings who are, as on our earth, constantly passing into a higher state of existence: and sure we are that the author of the *Christian Philosopher* does not need to be told that the *Heavens* were created for the reception of the spirits who are thus casting off their mortal coil, and rising to 'their destined height in the scale of being. And is it not the most moderate and becoming inference that can be drawn from all that we know of the character and proceedings of the Great Creator, that the ultimate end of creation, is that He may gratify His love in peopling the heavens with beings capable of enjoying it; and that as those heavens are immense beyond conception, or rather, like their maker, infinite, they cannot be peopled to eternity; and, consequently, that the myriads of earths which are the nurseries for the heavenly worlds must remain for ever?

Before the student proceeds farther in the study of geography, he will find it of essential advantage to make himself thoroughly acquainted with the use of the globes; to aid him in which we shall subjoin a few of the most useful, simple, and necessary definitions and problems.

The study of the celestial globe, it is true, belongs rather to astronomy than to geography; but from the intimate connexion subsisting between these two branches of science the use of both globes is generally taught at the same time, and indeed there is so much common to both that to separate them in a course of instruction would be highly detrimental to the student's progress.

There are ten principal circles represented upon globes, viz. six greater and four lesser ones. The greater circles are the horizon, meridian, and equinoctial, as it is called on the celestial, and equator on the terrestrial globe, the ecliptic drawn along the middle of the zodiac, and the two colures. The lesser circles, of principal use, are the two tropics and two polar circles. Of these circles some are fixed, and always obtain the same position; others moveable, according to the position of the observer. The fixed circles are the equator and ecliptic, with their parallels and secondaries; which are usually delineated upon the surface of the globes. The moveable circles are the horizon, with its parallels and secondaries.

The horizon is a broad wooden circle surrounding the globe, and dividing it into two equal parts, called the upper and lower hemispheres. It has two notches, to let the brazen meridian slip up and down, according to the different heights of the pole. On the flat side of this circle are described the twelve signs, the months of the year, the points of the compass, &c. The brazen meridian is a ring of brass, divided into degrees. It divides the globe into equal parts, called the eastern and western hemispheres. The quadrant of altitude is a thin pliable plate of brass, answering exactly to a quadrant of the meridian. It is divided into 90°, and has a notch, nut, and screw, to fix to the brazen meridian in the zenith of any place, where it turns round a pivot, and supplies the room of vertical circles. The hour-circle is a flat ring of brass, divided into twenty-four equal parts or hour-distances; and on the pole of the globe is fixed an index that turns round with the globe, and points out the hours upon the hour-circle. In modern globes the hour-circle is placed under the brass meridian, and is moveable on the axis of the globe, the meridian serving in place of an index. Lastly, there are generally added a compass and needle upon the pediment of the frame.

The surface of the celestial globe may be esteemed a just representation of the concave expanse of the heavens, notwithstanding its convexity; for it is easy to conceive the eye placed in the centre of the globe, and viewing the stars on its surface. The stars are all disposed in constellations under the forms of various animals, whose names and figures are represented on the celestial globe, which were first invented by the ancient astronomers and poets, and are still retained for the better distinction of these luminaries.

Various improvements have been made in the construction of globes, some of which are of great importance in working the problems; among the latest of these may be mentioned the terrestrial globe of Mr. Christie, which is so mounted as to exhibit the diurnal and annual revolutions of the earth. This globe, while it is made to revolve on its own axis, is moved, by the aid of two parallel levers, round a hollow sphere of ground glass, within which a lamp is placed, and from which a strong light is thrown upon the globe.

As, however, globes mounted either in this way, or on other improved principles, are in the possession of comparatively few persons, the following problems are selected for the use of those who have globes mounted in the common way.

PROBLEMS ON THE TERRESTRIAL GLOBE.

1. To find the latitude of any place.—Bring the given place to the brazen meridian, and observe what degree it is under, for that is the latitude required.

2. To rectify the globe for any given place.—Raise the pole so many degrees above the horizon as are equal to the latitude of the place; then, finding the sun's place, bring it to the meridian; screw the quadrant of altitude on the zenith; set the index of the hour-circle to the upper XII, and place the globe due north and south by the compass.

3. To find the longitude of a given placo.—Bring the place to the brazen meridian, and observe the degree of the equator under the same, for that expresses the longitude required.

4. To find any place by the latitude and longitude given.—Bring the given degree of longitude to the meridian, and under the given degree of latitude you will see the place required.

5. To find all those places which have the same latitude or longitude with those of any given place.—Bring the given place to the meridian ; then all those places which lie under the meridian have the same longitude: again, turn the globe round its axis; then all those places which pass under the same degree of the meridian with any given place have the same latitude with it.

6. To find all those places where it is noon at any given hour of the day in any place.—Bring the given place to the meridian, set the index to the given hour; then turn the globe till the said index points to the upper XII, and observe what places lie under the brass meridian; for to them it is noon at that time.

7. When it is noon at any one place, to find what hour it is at any other given place.—Bring the first

given place to the meridian, and set the index to the upper XII; then turn the globe till the other given place comes to the meridian, and the index will point to the hour required.

8. For any given hour of the day in the place where you are, to find the hour of the day in any other place.—Bring the place where you are to the meridian, set the index to the given hour, then turn the globe about; and when the other place comes to the meridian, the index will show the hour of the day there as required.

9. To find the distance between any two places in English miles.—Bring one place to the meridian, over which fix the quadrant of altitude; and then laying it over the other place, count the number of degrees thereon contained between them; which number multiply by 69½ (the number of miles in one degree) and the product is the number of English miles required.

10. To find how any one place bears from another.—Bring one place to the brass meridian, and lay the quadrant of altitude over the other, and it will show on the horizon the point of the compass on which the latter bears from the former.

11. To find those places to which the sun is vertical in the torrid zone for any given day.—Find the sun's place in the ecliptic for the given time, and bring it to the meridian, and observe what degree thereof it cuts; then turn the globe about, and all those places which pass under that degree of the meridian are those required.

12. To find what day of the year the sun will be vertical in any given place in the torrid zone.—Bring the given place to the meridian, and mark the degree exactly over it; then turn the globe round, and observe the two points of the ecliptic which pass under that degree of the meridian: lastly, see on the wooden horizon on what days of the year the sun is in those points of the ecliptic; for those are the days required.

13. To find those places in the north frigid zone where the sun begins to shine constantly without setting, on any given day between the 21st of March and the 21st of June.—Find the sun's place in the

ecliptic for the given day, bring it to the brazen meridian, and observe the degrees of declination; then all those places which are the same number of degrees distant from the pole are the places required to be found.

14. To find on what day the sun begins to shine constantly without setting, on any given place in the north frigid zone, and how long.—Rectify the globe to the latitude of the place, and, turning it about, observe what point of the ecliptic between Aries and Cancer, and also between Cancer and Libra, coincides with the north point of the horizon; then find by the calendar on the horizon what days the sun will enter those degrees of the ecliptic, and they will solve the problem.

15. To find the place to which the sun is vertical on any given day and hour.—Find the sun's place, and bring it to the meridian, and mark the degree of declination for the given hour; then find those places which have the sun in the meridian at that time; and among them that which passes under the degree of declination is the place required.

16. To find, for any given day and hour, those places wherein the sun is then rising and setting, or on the meridian: also those places which are enlightened, and those which are not.—Find the place to which the sun is vertical at the given time, and bring the same to the meridian, and elevate the pole to the latitude of the place: then all those places which are in the western semicircle of the horizon have the sun rising, and those in the eastern semicircle see it setting; and to those under the meridian it is noon. Lastly, all places above the horizon are enlightened, and all below it are in darkness.

17 The day and hour of a solar or lunar eclipse being given, to find all those places in which the same will be visible.—Find the place to which the sun is vertical at the given instant, and elevate the globe to the latitude of the place; then in most of those places above the horizon will the sun be visible during his eclipse; and all those places below the horizon will

see the moon pass through the shadow of the earth in her eclipse.

18. The length of a degree being given, to find the number of miles in a great circle of the earth, and thence the diameter of the earth.—Admit that one degree contains $69\frac{1}{2}$ English statute miles; then multiply 360 (the number of degrees in a great circle) by $69\frac{1}{2}$, and the product will be 25,020, the miles which measure the circumference of the earth. If this number be divided by 3.1416, the quotient will be $7963\frac{86}{100}$ miles for the diameter of the earth.

19. The diameter of the earth being known, to find the surface in square miles, and its solidity in cubic miles.—Admit the diameter to be 7964 miles; then multiply the square of the diameter by 3.1416, and the product will be 199250205 very nearly, which are the square miles in the surface of the earth. Again, multiply the cube of the diameter by 0.5236, and the product 264466789170 will be the number of the cubic miles in the whole globe of the earth.

20. To express the velocity of the diurnal motion of the earth.—Since a place in the equator describes a circle of 25020 miles in twenty-four hours, it is evident, that the velocity with which it moves is at the rate of $1042\frac{1}{2}$ in one hour, or $17\frac{3}{10}$ miles per minute. The velocity in any parallel of latitude decreases in the proportion of the co-sine of the latitude to the radius.

Thus, for the latitude of London, 51° 30′, say,

As radius	10.000000
To the co-sine of lat. 51° 30′ . .	9.794149
So is the velocity in the equator, $17\frac{5}{10}'$	2.238046
To the velocity of the city of London $10\frac{8}{10}'$	2.032195

That is, the city of London moves about the axis of the earth at the rate of $10\frac{8}{10}$ miles every minute of time: but this is far short of the velocity of the annual motion about the sun; for that is at the rate of more than 65,000 miles per hour.

PROBLEMS ON THE CELESTIAL GLOBE.

1. To rectify the globe.—Raise or elevate the pole to the latitude of the place; screw the quadrant of altitude in the zenith; set the index of the hour-circle to the upper XII, and place the globe north and south by the compass and needle; then it is a just representation of the heavens for the given day at noon.

2. To find the sun's place in the ecliptic.—Find the day of the month in the calendar on the horizon, and against it is the degree of the ecliptic which the sun is in for that day.

3. To find the sun's declination.—Rectify the globe, bring the sun's place in the ecliptic to the meridian, and the degree which it cuts in the meridian is the declination required.

4. To find the sun's right ascension.—Bring the sun's place to the meridian, and the degree of the equinoctial cut by the meridian is the right ascension required.

5. To find the sun's amplitude.—Bring the sun's place to the horizon, and the arch of the horizon intercepted between it and the east or west point is the amplitude, north or south.

6. To find the sun's amplitude for any given day and hour.—Bring the sun's place to the meridian, set the hour-index to the upper XII; then turn the globe till the index points to the given hour; then screwing the quadrant of altitude in the zenith, lay it over the sun's place, and the arch contained between it and the horizon will give the degrees of altitude required.

7. To find the sun's azimuth for any hour of the day.—Every thing being done as in the last problem, the arch of the horizon contained between the north point and that where the quadrant of altitude cuts it, is the azimuth east or west as required.

8. To find the time when the sun rises or sets.—Find the sun's place for the given day, bring it to the meridian, and set the index to XII; then turn the globe till the sun's place touches the east part of the horizon, the index will show the hour of its rising; turn the globe to the west part of the horizon, and the

index will show the time of its setting for the given day.

9. To find the length of any given day or night.—This is known by taking the number of hours between the rising and setting of the sun for the length of the day: and the remainder to twenty-four, for the length of the night.

10. To find the hour of the day, having the sun's altitude given.—Bring the sun's place to the meridian, and set the index to XII; then turn the globe in such a manner, that the sun's place may move along by the quadrant of altitude (fixed in the zenith) till it touches the degree of the given altitude, and the index will show the hour required.

11. To find the place of the moon, or any planet, for any given day.—Take White's Ephemeris, and against the given day of the month you will find the degree and minute of the sign which the moon or planet possesses at noon. The degree thus found being marked in the ecliptic on the globe by a small notch or otherwise, you may then proceed to find the declination, right ascension, latitude, longitude, altitude, azimuth, rising, southing, setting, &c. in the same manner as has been shown for the sun.

12. To explain the phenomena of the harvest moon. —In order to this we need only consider, that when the sun is in the beginning of Aries, the full moon on that day must be in the beginning of Libra : and since, when the sun sets, or the moon rises on that day, those equinoctial points will be in the horizon, and the ecliptic will then be least of all inclined thereto, the part or arch which the moon describes in one day, viz. 13°, will take up about an hour and a quarter ascending above the horizon; and, therefore, so long will be the time after sun-set, the next night, before the noon will rise. But at the opposite time of the year, when the sun is in the autumnal, and the full-moon in the vernal, equinox, the ecliptic will, when the sun is setting, have the greatest inclination to the horizon; and therefore 13° will in this case soon ascend, viz. in about a quarter of an hour; and so long after sun-set will the moon

rise the next day after the full: whence, at this time of the year, there is much more moonlight than in the spring; and hence this autumnal full moon came to be called the harvest moon, the hunter's or shepherd's moon; all which may be clearly shown on the globe.

13. To represent the face of the starry firmament, for any given hour of the night.—Rectify the globe, and turn it about till the index points to the given hour; then will all the upper hemisphere of the globe represent the visible half of the heavens, and all the stars on the globe will be in such situations as exactly correspond to those in the heavens, which may therefore be easily found, as will be shown in the 16th problem.

14. To find the hour when any known star will rise, or come upon the meridian.—Rectify the globe and set the index to XII; then turn the globe till the star comes to the horizon or meridian, and the index will show the hour required.

15. To find at what time of the year any given star will be on the meridian at XII at night.—Bring the star to the meridian, and observe what degree of the ecliptic is on the north meridian under the horizon; then find in the calendar on the horizon the day of the year against that degree, and it will be the day required.

16. To find any particular star.—First, find its altitude in the heavens by a quadrant, and the point of the compass it bears on: then, the globe being rectified, and the index turned to the given hour, if the quadrant of altitude is fixed on the zenith, and laid towards the point of the compass on which the star was observed, the star required will be found at the same degree of altitude on the quadrant, as it was by observation in the heavens.

The student may now proceed to attempt the construction of maps, which will contribute more to his advancement in the acquisition of the science than any other process connected with it. We can here only give an example or two of the method of procedure; but from these the learner will readily deduce the requisite information for the construction of maps of any description. In maps these three things are essentially requisite: 1. That all places have the same situation and distance from the great circles therein, as on the globe, to show their parallels, longitudes, zones, climates, and other celestial appearances. 2. That their magnitudes be proportionable to their real magnitudes on the globe. 3. That all places have the same situation, bearing, and distance, as on the earth itself.

The true chart performs the first and last of these very exactly, but fails extravagantly in the second; and indeed no kind of projection yet found can exhibit more than two of them at once, by reason of the great difference between a plane and convex superficies. The degrees of longitude are always numbered at top and bottom, and the degrees of latitude on the east and west sides. In all right-lined and general circular maps, except those of Wright's projection, the degrees of latitude on the sides are of an equal breath; and in all circular and right-lined maps, except the said Wright's and the plane charts, the degrees of longitude are unequal.

In general maps, the circles corresponding to those in the heavens are inscribed, viz. the equator is expressed by a straight east and west line; and the first meridian, the polar circles, the tropics, and the other meridians and parallels, which are drawn at every five or ten degrees, intersect each other at right angles. There may be as many different projections as there are points of view in which a globe can be seen, but geographers have generally chosen those which represent the poles at the top and bottom of the map; these, from the delineation of the lines of latitude and longitude, are called the stereographic, orthographic, and globular projections.

Geometrical Construction of the Globular Projection.

From the centre C, plate I, fig. 1. with any radius, as CB, describe a circle; draw the diameters AB, and 90, 90, at perfect right angles to one another, and divide them into nine equal parts; likewise divide each quadrant into nine equal parts; each of which contains ten degrees; if the scale admits of it, each of these divisions may be subdivided into degrees; next, to draw the meridian, suppose the meridians 80° W. of Greenwich, we have given the two poles 90, 90, and the point 80 in the equator, or diameter AB; describe a circle to pass through the three given points as follows: with the radius 90 set one foot of the compasses on the point 90, and describe the semicircles XX and ZZ, then remove the compasses to the point 80 on the equator, and describe the arcs, 1, 1, and 2, 2; where they intersect the semicircle; make the point, as at 1, and 2, and draw lines from 2 through the point 1 till they intersect the diameter BA continued in E: then will E be the centre from whence the meridian 90, 80, 90, must be drawn, and will express the meridian of 80° W. longitude from Greenwich; the same radius will draw the meridian expressing 140° W. longitude: in like manner, draw the next meridian with the radius CB, set one foot of the compasses in the point *d*, and describe the arcs *aa* and *bb*, then draw lines as before, which will give the point D, the centre of 90° W. longitude; so of all the rest. The parallels of latitude are drawn in the same manner, with this difference, that the semicircles XX and ZZ must be drawn from the points A and B, the extremities of the equator.

In the manner above described, Mr. Arrowsmith drew all the meridians and parallels of latitude to every degree on two hemispheres, which laid the foundation of his excellent map of the world.

We shall now show how the same thing may be done mechanically.

The Globular Projection of the Sphere on the Plane of a Meridian.

Draw the circle WNES, fig. 2, draw the two diameters NS and WE at right angles with each other.

Divide the arc of each quadrant into nine equal parts.

Divide the radii also in the same manner into ninety equal parts, A *b*.

The diameter N *b* is the meridian, and the diameter WE is the equator.

The other meridians are arcs of circles, for each of which, as we have seen, there are three given points through which it must pass, and those are the two poles NS, and a division on the semi-diameter WC, viz. either *a*, *b*, *c*, *d*, *e*, *f*, *g*, or *h*. The centres for these arcs will be in the line CE produced; and the centres for those on the other side will be on the line CW produced.

For the arc	the rad.		
S*a*N.	*aa*	= 90,61	the parts of which the radius contains 90.
S*b*N.	*bb*	= 93,82	
S*c*N.	*cc*	= 97,32	
S*d*N.	*dd*	= 106	
S*e*N.	*ee*	= 121,1	
S*f*N.	*ff*	= 149,7	
S*g*N.	*gg*	= 215,6	
S*h*N.	*hh*	= 410,7	

And for each of the arcs representing the parallels of lat. also there are three given points, viz. one of the divisions *k*, *l*, *m*, *n*, *o*, *p*, *q*, or *r*, upon the meridian SN, and the two corresponding divisions of the circumference. The centres for these arcs will fall on the line SN. produced both ways, and the following table shows the length of the radius of each equal part, in equatorial degrees, as in the former case.

For the arc			the radius			
80	*r*	80	*rr*	=	18,44	Of the equal parts of which the radius contains 90.
70	*q*	70	*qq*	=	39,75	
66½	A.	66½	A *Arctic*	=	48,19	
60	*p*	60	*pp*	=	65,3	
50	*o*	50	*oo*	=	97,71	
40	*n*	40	*nn*	=	143	
30	*m*	30	*mm*	=	210	
23½	T.	23½	T. *Tropic*	=	281,4	
20	*l*	20	*ll*	=	337,6	
10	*k*	10	*kk*	=	708,5	

To project a Map of any particular Part of the World.

There are several methods of projecting particular parts of the world; we shall notice only two. First, when the meridians and parallels of latitude are right lines.

To project a map of England after this method. England is situated between 2° E. and 6° 20′ W. from Greenwich, and between 50° and 56° N. lat.

Draw a base line A B, fig. 3, in the middle of which erect the perpendicular C D.

Assume a distance for a degree of lat. and set off as many degrees on CD as are wanted, which in this instance are 6; but as a little space beyond the limits of the country is generally left, set off 7.

Through these points draw lines parallel to AB, which will be parallels of latitude.

Respecting the degrees of longitude it must be observed, that on the equator they would be of the same length as they are on a meridian, but must gradually decrease from thence to 0 at the poles.

The following table exhibits the length, in geographical miles, of a degree of longitude for every degree of latitude.

Deg. Lat.	Geog. Miles.	Deg. Lat.	Geog Miles.	Deg. Lat.	Geog. Miles.	Deg. Lat.	Geog. Miles.
0	60,00	23	55,23	46	41,68	69	21,50
1	59,99	24	54,81	47	40,92	70	20,52
2	59,96	25	54,38	48	40,15	71	19,53
3	59,92	26	53,93	49	39,36	72	18,54
4	59,85	27	53,46	50	38,57	73	17,54
5	59,77	28	52,97	51	38,76	74	18,53
6	59,67	29	52,47	52	36,94	75	15,53
7	59,56	30	51,96	53	36,11	76	14,52
8	59,42	31	51,43	54	35,27	77	13,50
9	59,28	32	50,88	55	34,41	78	12,47
10	59,00	33	50,32	56	33,55	79	11,45
11	58,90	34	49,74	57	32,68	80	10,42
12	58,69	35	49,15	58	31,79	81	9,38
13	58,46	36	47,54	59	30,90	82	8,34
14	58,22	37	47,92	60	30,00	83	7,31
15	57,96	38	47,28	61	29,09	84	6,27
16	57,67	39	46,63	62	28,17	85	5,23
17	57,38	40	45,96	63	27,24	86	4,18
18	57,06	41	45,28	64	26,30	87	3,14
19	56,73	42	44,59	65	25,36	88	2,09
20	56,38	43	43,38	66	24,41	89	1,04
21	56.02	44	43,16	67	23,44	90	0,00
22	55,63	45	42,43	68	22,48		

To use this table, divide the assumed degree into sixty parts by a diagonal line, fig. 4; look for the number of miles answering to the degree of lat. 49, which is 39, 36, say 39½, which take off the scale at *a*, and set off four times from C towards A, and the same from C towards B. The top meridian is 56° deg. of lat., opposite which, in the table, is 33, 35, say 33½, which take from the scale at *b*, and set off four times from D towards E, and the same from D towards F. Draw the meridian lines to the corresponding divisions at top and bottom, of which O O is the meridian of London.

Secondly. When the meridians and parallels are curved lines.

To project a map of Europe by this method. Draw a base line GH, fig. 5, in the middle of which erect the perpendicular JP, and assume any distance for 10° of latitude.

Europe extends from 36° to 72° N. lat.

Let the point J be 30°, from which set off six of the assumed distances to P, which will be the N. pole.

Number the distances 40, 50, 60, &c.

On the centre P, describe arcs passing through the points of division on the line JP, which will be parallels of latitude.

Divide the space assumed for 10° of lat. into 60 parts by a diagonal line, fig. 6.

Look into the foregoing table for the number of miles answering to 30°, which is 51, 96, say 52, which take from the scale at *b*.

Set this distance off on the arc 30, 30, from the centre line JP both ways.

Do the same for 40°, 50°, 60°, &c.

Through the corresponding divisions, on all the arcs, draw curve lines; which will represent the meridians.

Number the degrees of lat. and long., which will complete the diagram.

Those who wish to prosecute this interesting branch of science to a greater extent than the above sketch comprehends may consult with profit Jamieson's Treatise on the Construction of Maps.

Having thus given a brief view of the science which treats of the surface of the earth, taken in its most general sense; we shall now proceed to treat of the rich and beautiful variety of vegetable productions with which the habitable parts of the globe are adorned.

CHAPTER II.

BOTANY.

Botany, may be defined the science which teaches the knowledge of the vegetable kingdom. The word is derived from the Greek *βοτανη*, an herb; and this again may easily be traced to its primitive, *βοω*, or *βοσκω*, to feed: an apt derivation, since plants have ever been regarded as the food of a large portion of animals. The study of botany, then, may be said to include—the practical discrimination, methodical arrangement, and systematical momenclature of vegetables.

In describing the characters of plants, we shall treat of their roots, buds, trunk, leaves, props, inflorescence. fructification, and classification.

1. Roots are necessary to plants, to fix and hold them in the earth, from which they imbibe nourishment. Roots are either *annual*, or living for one season, as in barley; *biennial*, which survive one winter, and after perfecting their seed, perish at the end of the following summer, as wheat; or *perennial*, which remain and produce blossoms for an indefinite number of years, as those of trees and shrubs in general. The root consists of two parts, the *caudex* and the *radicula*. The *caudex*, or stump, is the body or knob of the root, from which the trunk and branches ascend, and the fibrous roots descend. The *radicula* is the fibrous part of the root branching from the *caudex*. Roots are: 1. *Fibrous*, or consisting entirely of fibres, as in many grasses and herbaceous plants. 2. *Creeping*, or having a subterraneous stem, spreading horizontally in the ground, throwing out numerous fibres, as in mint

and couch-grass. 3. *Spindle-shaped,* as in the radish and carrot, which produce numerous fibres for the absorption of nutriment. 4. *Stumped,* or apparently bitten off, as in the primrose. 5. *Tuberous* or knobbed, as in the potatoe, which consist of fleshy knobs, connected by common stalks or fibres. 6. *Bulbous,* as in the crocus. 7. *Granulated,* or having a cluster of little bulbs or scales connected by a common fibre, as in the saxifrage.

II. Buds. These are, in most instances, guarded by scales, and furnished with gum or wooliness, as an additional defence. Buds are various in their forms, but very uniform in the same species, or even genus. They enfold the embryo plant.

III. Trunk. The trunk of trees includes the stems or stalks, which are of seven kinds. The stem, as it advances in growth, is either able to support itself, or twines round other bodies. It is either *simple,* as in the lily; or *branched,* as in other plants. The parts are: 1. *Caulis,* the stem which bears both leaves and flowers, as the trunks and branches of all trees and shrubs, as well as of many herbaceous plants. 2. *Culmus,* a straw or culm, the peculiar stem of grasses, rushes, and similar plants. 3. *Scapus* or stalk, springs immediately from the root, bearing flowers and fruit, but not leaves, as in the primrose or cowslip. 4. *Pedunculus,* the flower-stalk, springs from the stem or branches, bearing flowers and fruit, but not leaves. 5. *Petiolus,* the foot-stalk, is applied exclusively to the stalk of a leaf.

IV. Leaves. These are generally so formed as to present a large surface to the atmosphere. When they are of any other hue than green, they are said, in botanical language, to be *coloured.* The internal surface of a leaf is highly vascular and pulpy, and is clothed with a cuticle very various in different plants; but its pores are always so constructed as to admit of the requisite evaporation or absorption of *moisture,* as well as to admit and give out air. *Light* also acts through this cuticle in a different manner. The effect of moisture must have been observed by every one. By absorption from the atmosphere the leaves are refreshed; but by evaporation, especially when separated from their stalks, they soon fade and wither. The nutricious juices, imbibed from the earth, and become *sap*, are carried by appropriate vessels into the substance of the leaves, and these juices are *returned* from each leaf, not into the wood again, but into the bark. The sap is carried into the leaves for the purpose of being acted upon by *air* and *light*, with the assistance of heat and moisture. By all these agents a most material change is wrought in the component parts of the sap, according to the nature of the secretions elaborated, whether resinous, oily, mucilaginous, saccharine, bitter, acrid, or alkaline.

The *green* colour of the leaves is owing to the action of light, but they are subject to a disease by which they become partially spotted or streaked, and in this state are said to be variegated. The irritable nature of some leaves is very extraordinary. The *mimosa pudica*, or sensitive plant, common in our hot-houses, when touched by any extraneous body, folds up its leaves, one after another, and the foot-stalks droop, as if dying.

V. PROPS, or fulcra. These are: 1. *Stipula*, a leafy appendage to the true leaves, or to their stalks, for the most part in pairs. 2. *Bractia*, a leafy appendage to the flower, or to its stalk. 3. *Spina*, a thorn proceeding from the wood itself, as in the wild-pear tree, which loses its thorns by cultivation. 4. *Aculeus*, a prickle, proceeding from the bark only, as in the rose and bramble. 5. *Cirrus*, a tendril or clasper, is a support for weak stems, by which they are enabled to climb rocks, or the trunks of lofty trees. 6. *Glandula*, a gland, is a small tumour, secreting a sweet, resinous, fragrant liquor, as on the calyx or cup of the moss-rose, and the foot stalks of passion flowers. 7. *Pilus*, a hair, which includes all the various kinds of pubescence, bristles, wool, &c. some of which discharge a poison, as in the nettle, causing great irritation, whenever they are touched in such a manner as that their points wound the skin. Hence arose the following lines:

"Tender-handed touch a nettle,
And it stings you for your pains;
Grasp it like a man of mettle,
And it soft as silk remains."

VI. INFLORESCENCE, or the different kinds or modes of flowering, are, 1. *Verticillus*, a whorl, in which the flowers surround the stem in a garland or ring, as in the mints, dead-nettles, &c. 2. *Racunus*, a cluster, bears several flowers, each on its own stalk, like a bunch of currants. 3. *Spica*, a spike, is composed of numerous crowded flowers, ranged along an upright, common stalk, expanding progressively, as in wheat and barley. 4. *Corymbus*, a corymb, is a flat-topped spike as in the cabbage and wall-flower. 5. *Fasciculus*, a close bundle of flowers, as in the sweetwilliam. 6. *Cayitulam*, a head or tuft, as in the globe-amaranthus and thrift. 7. *Umbella*, an umbel, consists of several stalks, called rays, spreading like an umbrella, as in parsley, carrot, and hemlock. 8. *Cyma*, a cyme, or stalks springing from a common centre, and afterwards irregularly subdivided, as in the lauristinus, and elder. 9. *Paniculus*, a panicle, a loose subdivided bunch of flowers, as in the oat 10. *Thyrsus*, a bunch, is a very dense panicle inclining to an oval figure, as in the lilac.

VII. FRUCTIFICATION. Under this term are comprehended not only the parts of the fruit, but also those of the flower, which last are necessary for bringing the former to perfection. Fructification consists of seven parts, two only of which are *essential*, viz. *stamen* and *pistil*, since without them no plant can produce seeds. 1. *Calyx*, a flower cup, or external covering of the flower; to this belong the perianthum; involucrum: amentum, or cat-kin; spatha, or sheath; gluma, or husk; perichætium, or scaly sheath; and volva, the wrapper. 2. *Corolla*, or little crown, is situated within the calyx, and consists in general of the coloured leaves of a flower;—the petalum, or petal, and the nectarium, or nectary, belonging to the corolla. 3. *Stamina*, the stamens, are various in number, in different flowers, and are situated within the corolla. The stamen consists of a filamentum, or filament, and the anthera, or anther. The cells of the latter contain the pollen, or fecundating dust. 4. *Pistilla,* the pistils, stand in the centre of the circle formed by the stamens. and consist of the germen or rudiments of the future fruit or seed; the style, which elevates the stigma; and the stigma, which is destined to receive the pollen. 5. *Pericarpium,* the seed vessel, is formed from the germen enlarged, and is of the following kinds: a capsular, or capsule; siliqua, or pod; legumen, or legume, the fruit of the pea-kind; drupa, stone-fruit; pomum, an apple; bacca, a berry; and strobilus, a cone. 6. *Semina,* the seeds, are composed of the embryo or germ, called by Linnæus, corculum, or little heart; the cotyledones, or seed-lobes, almost universally two in number; albumen, the white; vitellus, the yolk; testa, the skin; and hilum, the scar.

Seeds are often accompanied by appendages or accessary parts; as, pellicula, the pellicle; arillus, the tunic; pappus, the seed-down; cauda, a tail; rostrum, a beak. To which may be added various spines, hooks, scales, and crests, generally serving to attach such seeds as are furnished with them to the rough coats of animals, and thus promote their dispersion. 7. *Receptaculum,* the receptacle, is the base which receives the other parts of the fructification. It is *proper* when it supports the parts of a single fructification only; when it is a base to which only the parts of the flower are joined, and not the germen, it is called a receptacle of the flower; in this case the germen being placed below the receptacle of the flower, has a base of its own, which is called the receptacle of the fruit, and it is termed a receptacle of the seeds, when it is a base to which the seeds are fastened within the pericarpium. It is called *common* when it supports a head of flowers.

VIII. CLASSIFICATION. The system of Linnæus, now generally acknowledged and adopted, is founded on the number, situation, and proportion of the *stamens* and *pistils,* whose uses and structure have been just explained. The following twenty-four classes owe their distinctions principally to the stamens. 1. *Mon-*

andria, one stamen. 2. *Diandria,* two stamina. 3. *Triandria,* three. 4. *Tetrandria,* four. 5. *Pentandria,* five. 6. *Hexandria,* six. 7. *Heptandria,* seven. 8. *Octandria,* eight. 9. *Enneandria,* nine. 10. *Decandria,* ten. 11. *Dodecandria,* twelve. 12. *Icosandria,* twenty or more stamina, inserted into the calyx. 13. *Polyandria,* all above twenty inserted into the receptacle. 14. *Didynamia,* four stamina, two long and two short. 15. *Tetradynamia,* six stamina, four long and two short. 16. *Monadelphia,* the stamina united into one body by the filaments. 17. *Diadelphia,* the stamina united into the bodies by the filaments. 18. *Polyadelphia,* the stamina united into three or more bodies by the filaments. 19. *Syngenesia,* anthers united into a tube. 20. *Gynandria,* stamens inserted either upon the style or germen. 21. *Monœcia,* stamens and pistils in separate flowers, but on the same plant. 22. *Diœcia,* stamens and pistils, like the former in separate flowers, but on two separate plants. 23. *Polygamia,* stamens and pistils separate in some flowers, united in others, either on one, two, or three distinct plants. 24. *Cryptogamia,* stamens and pistils, either not well ascertained, or not to be numbered with certainty.

The *orders,* or subdivisions of the classes, are generally marked by the number of the pistils, or by some other circumstances equally intelligible. The names of these, as well as of the classes, are both of Greek derivation, and designate the functions of the respective organs.

In the following table the reader will find the names of the classes, and also those of the several orders which are included in each class.

TABLE OF THE ORDERS.

Classes.	*Number and Names of the Orders.*
1. Monandria.	2. Monogynia, Digynia.
2. Diandria.	3. Monogynia, Digynia, Trigynia.
3. Triandria.	3. Monogynia, Digynia, Trigynia.
4. Tetrandria.	3. Monogynia, Digynia, Tetragynia.
5. Pentandria.	6. Monogynia, Digynia, Trigynia, Tetragynia, Pentagynia, Polygynia.

Classes.	*Number and Names of the Orders.*
6. Hexandria.	5. Monogynia, Digynia, Trigynia, Tetragynia, Polygynia.
7. Heptandria.	4. Monogynia, Digynia, Tetragynia, Heptagynia.
8. Octandria.	4. Monogynia, Digynia, Trigynia, Tetragynia.
9. Enneandria.	3. Monogynia, Trigynia, Hexagynia.
10. Decandria.	5. Monogynia, Digynia, Trigynia, Pentagynia, Decagynia.
11. Dodecandria.	5. Monogynia, Digynia, Trigynia, Pentagynia, Dodecagynia.
12. Icosandria.	5. Monogynia, Digynia, Trigynia, Pentagynia, Polygynia.
13. Polyandria.	7. Monogynia, Digynia, Trigynia, Tetragynia, Pentagynia, Hexagynia, Polygynia.
14. Didynamia.	2. Gymniospermia, Angiospermia.
15. Tetradynamia.	2. Siliculosa, Siliquosa.
16. Monadelphia.	8. Triandria, Pentandria, Octandria, Enneandria, Decandria, Endecandria, Dodecandria, Polyandria.
17. Diadelphia.	4. Pentandria, Hexandria, Octandria, Decandria.
18. Polyadelphia.	4. Pentandria, Dodecandria, Icosandria, Polyandria.
19. Syngenesia.	6. Polygamia æqualis, Polygamia superflua, Polygamia frustrania, Polygamia necessaria, Polygamia segregata, Monogamia.
20. Gynandria.	9. Diandria, Triandria, Tetrandria, Pentandria, Hexandria, Octandria, Decandria, Dodecandria, Polyandria.
21. Monœcia.	11 Monandria, Diandria, Triandria, Tetrandria, Pentandria, Hexandria, Heptandria, Polyandria, Monadelphia, Syngenesia, Gynandria.
22. Diœcia.	15. Monandria, Diandria, Triandria, Tetrandria, Pentandria, Hexandria, Octandria, Enneandria, Decandria, Dodecandria, Icosandria, Polyandria, Monadelphia, Syngenesia, Gynandria.
23. Polygamia.	3 Monœcia, Diœcia, Triœcia.
24. Cryptogamia.	4. Filices, Musci, Algæ, Fungi.
Appendix.	1. Palmæ.

In pursuing the study of this delightful science, the student should provide himself with a good microscope, by the help of which he will be enabled to discover numerous wonders, which must for ever escape the unassisted sight of the naked eye. We might enrich our pages with some highly interesting instances of the truth of this remark, but shall adduce only one, as affording a striking proof that there exists a gradation of worlds downwards, as well as upwards. It is from the pen of Sir John Hill.

"The principal flower in an elegant bouquet was a carnation; the fragrance of this led me to enjoy it more frequently and near: the sense of smelling was not the only one affected on these occasions; while that was satiated with the powerful sweet, the ear was constantly attacked by an extremely soft, but agreeable, murmuring sound. It was easy to know, that some animal within the covert must be the musician, and that the little noise must come from a little creature suited to produce it. I instantly distended the lower part of the flower, and placing it in a full light, could discover troops of little insects frisking with wild jollity among the narrow pedestals that supported its leaves, and the little threads that occupied its centre. What a fragrant world for their habitation! What a perfect security from all annoyance, in the dusky husk that surrounded the scene of action!

"Adapting a microscope to take in, at one view, the whole base of the flower, I gave myself an opportunity of contemplating what they were about, and this for the space of many days together, without giving them the least disturbance. Thus I could discover their economy, their passions, and their enjoyments. The microscope, on this occasion, had given what nature seemed to have denied to the objects of contemplation. The base of the flower extended itself under its influence, to a vast plain; the slender stems of the leaves became trunks of so many stately cedars; the threads in the middle seemed columns of massy structure, supporting at the top their several ornaments; and the narrow spaces between were enlarged in walks, parterres, and terraces.

"On the polished bottoms of these, brighter than Parian marble, walked in pairs, alone, or in larger companies, the winged inhabitants; these, from little dusky flies, for such only the naked eye would have shown them, were raised to glorious glittering animals, stained with living purple, and with a glossy gold, that would have made all the labours of the loom contemptible in the comparison. I could at leisure, as they walked together, admire their elegant limbs, their velvet shoulders, and their silken wings; their backs vying with the empyrean in its blue, and their eyes each formed of a thousand others, out-glittering the little planes on a brilliant; above description, and too great almost for admiration.

"I could observe them here singling out their favourite females; courting them with the music of their buzzing wings, with little songs, formed for their little organs, leading them from walk to walk, among the perfumed shades, and pointing out to their taste the drop of liquid nectar just bursting from some vein within the living trunk—here were the perfumed groves, the more than mystic shades, of the poet's fancy realized. Here the happy lovers spent their days in joyful dalliance, or, in the triumph of their little hearts, skipped after one another from stem to stem among the painted trees, or winged their short flight to the close shadow of some broader leaf, to revel undisturbed in the heights of all felicity."

With such scenes as these the reader, no doubt, would soon become fascinated, and dwell on the contemplation of them with unmingled delight; but he must now accompany us while we attempt to explore the internal structure of the globe.

CHAPTER III.

GEOLOGY.

THE term Geology is derived from the Greek words γη or γεα *the earth*, and λογος *a discourse*, and is used to signify a description of the structure of the earth.

As a branch of inductive science, geology is of very modern date; for though the attention of men has long been directed to a theory of the earth, the formation of such a theory is incompatible with any but an advanced state of physical knowledge. Few studies, indeed, are attended with greater difficulty; none in which the subject is more complex; appearances so diversified and scattered; and where the causes that have operated are so remote from the sphere of ordinary observation. Works on the subject of geology are multiplying at the present time with unexampled rapidity; to suppose, however, that they are all either interesting or useful, would be absurd; and the inquirers on this interesting subject will find the most satisfactory and scientific information from the writings of such men as Greenough, Conybeare, Philips, Buckland, D'Auluisson, and the justly celebrated Cuvier.

The following brief sketch of the subject is taken from the excellent view given of this science in a work by Messrs. Conybeare and Philips, entitled Outlines of the Geology of England and Wales. Some additions by Dr. Ure occasionally occur, and are marked with asterisks. This study may be divided, like most others, into two parts, observation and theory. By the first we learn the relative positions of the great rocky or mineral aggregates that compose the crust of our globe; through the second we endeavour to penetrate into the causes of these collocations.

Werner's Table of the different Mountain Rocks, from Jameson.

Class I.—Primitive rocks.

1. Grafite. 2. Gneiss. 3. Mica-slate. 4. Clay-slate. 5. Primitive limestone. 6. Primitive trap. 7. Serpentine. 8. Porphyry. 9. Sienite. 10. Topaz-rock. 11. Quartz-rock. 12. Primitive flinty-slate. 13. Primitive gypsum. * 14. White stone.

Class II.—Transition rocks.

1. Transition limestone. 2. Transition trap. 3. Greywacke. 4. Transition flinty slate. 5. Transition gypsum.

Class III.—Floetz rocks.

1. Old red sandstone, or first sandstone formation. 2. First or oldest floetz limestone. 3. First or oldest floetz gypsum. 4. Second or variegated sandstone formation. 5. Second floetz gypsum. 6. Second floetz

limestone. 7. Third floetz limestone. 8. Rock salt formation. 9. Chalk formation. 10. Floetz-trap formation. 11. Independent coal formation. 12. Newest floetz-trap formation.

Class IV.—Alluvial rocks.

1. Peat. 2. Sand and gravel. 3. Loam. 4. Bog-iron ore. 5. Nagelfluh. 6. Calc-tuff. 7. Calc-sinter.

Class V.—Volcanic rocks.

* Pseudo-volcanic rocks.

1. Burnt clay. 2. Porcelain jasper. 3. Earth slag. 4. Columnar clay ironstone. 5. Polier, or polishing slate.

** *True volcanic rocks.*

1. Ejected stones and ashes. 2. Different kinds of lava. 3. The matter of muddy eruptions.

The primitive rocks lie undermost, and never contain any traces of organized beings imbedded in them. The transition rocks contain comparatively few organic remains, and approach more nearly to the chemical structure of the primitive, than the mechanical of the secondary rocks. As these transition rocks were taken by Werner from among those which in his general arrangement were called secondary, the formation of that class made it necessary to abandon the latter term. To denote the mineral masses reposing in his transition series, he accordingly employed the term floetz rocks, from the idea that they were generally stratified in planes nearly horizontal, while those of the older strata were inclined to the horizon at considerable angles.

But this holds good with regard to the structure of those countries only which are comparatively low; in the Jura chain, and on the borders of the Alps and Pyrenees. Werner's floetz formations are highly inclined. Should we therefore persist in the use of this term, says Mr. Conybeare, we must prepare ourselves to speak of vertical beds of floetz (*i. e.* horizontal) limestone, &c. As the inquiries of geologists extended the knowledge of the various formations, Werner, or his disciples, found it necessary to subdivide the bulky class of floetz rocks into floetz, and newest floetz, thus completing a fourfold enumeration. Some writers have bestowed the term *tertiary* on the newest floetz rocks of Werner. The following synoptical view of geological arrangement is given by the Rev. Mr. Conybeare.

CHARACTER.	PROPOSED NAMES.	WERNERIAN NAMES.	OTHER WRITERS.
1. Formations (chiefly of *sand* and *clay* above the chalk).	*Superior order.*	Newest floetz class.	Tertiary class.
2. Comprising, a. Chalk. b. Sands and clays, *beneath the chalk.* c. Calcareous freestones (*oolites*) and argillaceous beds. d. *New red sandstone, conglomerate, and magnesian limestone*	*Supermedial order.*	Floetz class.	Secondary class.
3. Carboniferous rocks, comprising, a. *Coal measures.* b. *Carboniferous limestone.* c. *Old red sandstone.*	*Medial order.*	Sometimes referred to the preceding, sometimes to the succeeding class, by writers of these schools; very often the coal measures are referred to the former, the subjacent limestone and sandstone to the latter.	
4. *Roofing slates*, &c. &c.	*Submed. order.*	Transition class.	Intermed. class.
5. *Mica slate*, *gneiss*, *granite*, &c.	*Inferior order.*	Primitive class.	Primitive class.

In all these formations, from the lowest to the highest, we find a repetition of rocks and beds of similar chemical composition; *i. e.* siliceous, argillaceous, and calcareous, but with a considerable difference in texture; those in the lowest formations being compact, and often crystalline, while those in the highest and most recent are loose and earthy. These repetitions form what the Wernerians call formation suites. We may mention,

1. The *limestone suite.* This exhibits, in the inferior or primitive order, crystalline marbles; in the two next, or transition and carboniferous orders, compact and subcrystalline limestones (Derbyshire limestone); in the supermedial or floetz order, less compact limestone (lias), calcareous freestone (Portland and Bath stone), and chalk; in the superior or newest floetz order, loose earthy limestones.

2. The *argillaceous suite* presents the following gradations; clay-slate, shale of the coal measures, shale of the lias, clays alternating in the oolite series, and that of the sand beneath the chalk; and, lastly, clays above the chalk.

3. The *siliceous suite* may (since many of the sandstones of which it consists present evident traces of felspar and abundance of mica, as well as grains of quartz, and since mica is more or less present in every bed of sand) perhaps deserve to have granite placed at its head, as its several members may possibly have been derived from the detritus of that rock: it may be continued thus: quartz rock and transition sandstone, old red sandstone, millstone-grit, and coal-grits, new red sandstone, sand, and sandstone beneath the chalk, and above the chalk. In all these instances a regular diminution in the degree of consolidation may be perceived in ascending the series.

We noticed before, that the remains of vegetables and animals are confined to the secondary formations. We have now to add, that they are not irregularly dispersed throughout the whole series of these formations, but disposed as it were in families, each formation containing an association of species peculiar in many instances to itself, widely differing from those of other formations, and accompanying it throughout its whole course; so that at two distinct points on the line of the same formation, we are sure of meeting the same general assemblage of fossil remains. It will serve to exemplify the laws which have been stated, if the observer's attention is directed to two of the most prominent formations of this island; namely, the chalk and the limestone which underlie the coal in Northumberland, Derbyshire, South Wales, and Somerset. Now if he examines a collection of fossils from the chalk of Flamborough-Head, or from that of Dover-Cliffs, or, it may be added, from Poland or Paris, he will find eight or nine species out of ten the same; he will observe the same echinites associated with the same shells; nearly one-half of these echinites he will perceive to belong to divisions of that family unknown in a recent state, and indeed in any other fossil bed except the chalk.

If he next proceeds to inspect parcels of fossils from the carboniferous limestone, he will in the same manner find them to agree with each other, from whichever of the above localities they may have been brought; that is, he will find the same corals, the same echinites, the same productæ, terebratulæ, spiriferæ, &c. But, lastly, if he compares the collection from the chalk with that from the mountain lime, he will not find one single instance of specific agreement, and in very few instances any thing that would deceive even an unpractised eye, by the superficial resemblance of such an agreement.

If we cast a rapid view over the phenomena of this distribution, the subject must appear to present some of the most singular problems which can engage the attention of the inquirer into nature. First, We have a foundation of primitive rocks destitute of these organic remains; in the next succeeding series (that of transition), corals, encrinites, and testacea, different however from those now known, appear at first sparingly. The fossil remains of the carboniferous limestone are nearly of the same nature with those in the transition rocks, but more abundant; the coal-measures (coal strata), however, themselves, which repose on this limestone, present scarcely a single shell or coral; but, on the contrary, abound with vegetable remains, ferns, reeds of unknown species, and large trunks of succulent plants, *strangers to the present globe*. Upon the coal rest beds again containing marine remains (the magnesian limestone), then a long interval (of new red sandstone) intervenes, destitute almost, if not entirely, of organic remains, preparing the way, as it were, for a new order of things. This order commences in the lias, and is continued in the oolites, green and iron sands, and chalk. All these beds contain corals, encrinites, echinites, testacea, crustacea, vertebral fishes, and marine oviparous quadrupeds, yet widely distinguished from the families contained in the lower beds of the transition and carboniferous class, and particularly distinguished among themselves, according to the bed which they occupy. Hitherto the remains are always petrified, *i. e.* impregnated in the mineral substance in which they are imbedded. But, lastly, in the strata which cover the chalk, we find the shells merely preserved, and in such a state, that when the clay or sand in which they lie is washed off, they might appear to be recent, had they not lost their colour, and become more brittle. Here we find beds of marine shells alternating with others peculiar to fresh water, so that they seem to have been deposited by *reciprocating inundations of fresh and salt water.* In the highest of the regular strata, the crag, we at length can find an identity with the shells at present existing on the same coast; and, lastly, over all these strata indiscriminately there is spread a covering of gravel (seemingly formed by the action of a deluge, which has detached and rounded by attrition fragments of the rocks over which it swept), containing the remains of numerous land quadrupeds, many of them of unknown genera or species (the mastodon, and the fossil species of elephant, or mammoth, bear, rhinoceros, and elk), mingled with others (hyænas, &c.) equally strangers to the climates where they are now found, yet associated with many at present occupying the same countries.

Another class of substances imbedded in the secondary strata, and throwing light on the convulsions amidst which they have been formed, are the pebbles, or rolled fragments of rocks, older than themselves, which they are often found to contain.

The necessary inferences from this fact are, first, The rock whence the fragments were derived must have been consolidated, and, subsequently to that consolidation, have been exposed to the mechanical violence (probably the action of agitated waters) which tore from it these masses, and rounded them by attrition, before the rock in which these fragments are now imbedded was formed; and, secondly, Since loose gravel beds (and such must have been the original form of these, though now consolidated into conglomerate rocks) cannot be accumulated to any extent from the action of gravity on a highly inclined plane, we are sure, when we find such beds, as we often do in nearly vertical strata, that this cannot have been their original position, but is one into which they have been forced by convulsions which have dislocated them subsequently to their consolidation. These consolidated gravel beds are called conglomerates, breccias, or pudding-stones; we find them among the transition rock, in the old red sandstone, in the mill-stone grits and coal-grits, in the lower members of the new red sandstone, in the sand strata beneath the chalk, and in the gravel beds associated with the plastic clay, and interposed between the chalk and great London clay.

From the occurrence of the marine remains lately noticed, occupying, as they do, rocks spread over two-thirds of the surface of every part of our continents which have been explored, and rising to the highest situations, even to the loftiest summits of the Pyrenees, and still more elevated points on the Andes, it is an inevitable inference, that the greater part of those continents have not only been covered by, but have been formed of, materials collected within the bosom of the ocean; that we inhabit countries which we may truly call *factas ex æquore terras.*

The great and fundamental problem, therefore, of theoretical geology, is obviously to assign adequate causes for the change of level in this ocean, which has permitted these masses, which once formed the bottom of its channel, to rise in hills and mountains above its waves. The causes which it is possible to imagine are reducible to two general classes. First, The decrease of the absolute quantity of water. This must have resulted from causes entirely chemical, namely, the decomposition of some portion of the water, its constituents entering into new forms of combination; and its formation in the rocks formed beneath it. It is probable that these causes have operated to some degree, but it seems impossible to ascribe to them the very great difference of level for which we have to account.

The second class of possible causes is entirely mechanical; those, namely, which may have produced a change of relative level without any diminution of absolute quantity in the waters.

The causes of this kind which have been proposed are, first, The absorption of the waters into a supposed central cavity; but the now ascertained density of the earth (being greater than that which would result from an entirely solid sphere of equal magnitude of the most compact known rock) renders the existence of any such cavity very doubtful.

Secondly, A writer in the Journal of the Royal Institution, vol. ii. has proposed the very ingenious hypothesis, that a change of temperature of a few degrees will, from the unequal expansibility of the materials of land and water, sufficiently account for this change of level.

Thirdly, It has been ascribed to violent convulsions, which have either heaved up the present continents, or, which amounts to the same thing (as the same relative change must have taken place in either view), depressed the present channel of the ocean. If the violent elevation of the continent, or depression of the channel of the ocean, supposed in the last mentioned hypothesis, really took place, it must have left traces in the disturbed, contorted, and highly inclined position of the strata; and these disturbances must be the greatest where the change of level has been the greatest, *i. e.* in the neighbourhood of the loftiest mountains. Now this is actually the case.*

In support of the hypothesis which ascribes an important part to volcanic agency in modifying the surface of our planet, the following, at least plausible, arguments might be adduced.

1. It must be kept in view, that the object is to assign an adequate cause for the undoubted fact of the emergence of the loftiest mountains of the present continent; and that when so mighty an effect is to be accounted for, the mind must be prepared to admit, without being startled, causes of a force and energy greatly exceeding those with which we are acquainted from actual observation.

2. The broken and disturbed state, and inclined position of the strata composing those continents, many of which must have been at the time of their original formation horizontal, indicate, as we have seen, that one at least of the causes operating to effect this great change of relative level between the land and waters was the elevation of the former by mechanical force.

3. The only agent with which we are acquainted, whose operation bears any analogy to the effects above specified, is the volcanic energy which still occasionally forms new islands, and elevates new mountains.

4. Although these effects are now indeed partial and limited, yet there is certain proof that volcanic agency has formerly been much more active; the extinct volcanoes of the Rhine, Hungary, and Auvergne, as well as those which occupy so large a portion of Italy, where only one remains in activity, concur in proving that at present we experience only the expiring efforts, as it were, of those gigantic powers which have once ravaged the face of nature.

5. If to this certain proof of the greater prevalence of volcanic convulsions in earlier, but still comparatively recent, periods of the history of our planet, we add the presumption that the trap rocks (so singularly intruded among the regular strata, and producing, where they traverse those strata, so precisely the effects of heat acting under compression, and so different in all their phenomena from formations decidedly aqueous) were of volcanic origin, we shall find that scarcely a country exists, which has not been

a prey to the ravages of this powerful principle. If, with many of the best geological observers, (Doctor M'Culloch, Von Buch, Necker, &c.) we incline to extend the same conclusions to granite rocks, a mass of volcanic power, clearly adequate to all the required effects, is provided.

6. The question will undoubtedly present itself, what is the source of volcanic action? And sufficient proof exists that this source is deeply seated beneath the lowest rocks with which our examination of the earth's surface makes us acquainted; for in Auvergne, the lavas have evidently been erupted from beneath the primitive rocks.

7. The very important recent discoveries with regard to the increased temperature noticed in descending deep mines, &c. by Messrs. Fox and Fourrier, will, if confirmed by further examination, prove, that some great source of heat exists beneath the earth's crust.

8. A degree of presumption may be thought to arise from these considerations, that the crust of the earth rests on a heated nucleus, the true source of volcanic energy. If this nucleus be in a fluid or viscous state, its undulations would readily account for the convulsions which have affected that crust, both in originally dislocating and elevating portions of its strata, and in the actual phenomena of earthquakes (of many of which phenomena no other hypothesis appears to offer a sufficient explanation), while, at the same time, it would afford an adequate reason for the figure of the globe as a spheroid of rotation.

9. On this supposition, we should at once perceive a reason why the effects of the volcanic force may have been much more violent in earlier periods, while that mass of deposites which now covers the supposed volcanic nucleus was but gradually forming over it, than at present; and we shall also find a reason for the higher temperature which many of the remains of both the animal and vegetable kingdoms, found in the strata of countries now too cold for the existence of their recent analogies, appear to indicate as having formerly prevailed.

10. It must be remembered, that one of the essential

conditions of the theory above sketched is, the operation of volcanic agency beneath the pressure of an incumbent ocean; and that it does not, therefore, in any degree question the Neptunian origin of the majority of the rocks which have evidently been formed in the bosom of the ocean. With regard to the trap rocks alone, and perhaps the granitic, does it venture even to insinuate an opposite mode of formation?

Mr. Conybeare next shows, that the Wernerian generalization of the phenomena is too hasty. It supposes the basset edges of the strata to occupy levels successively lower and lower in proportion as they are of less ancient formation, and as they recede from the primitive chains, forming the edges of the basins in which they have been deposited. For if we compare the basset edges of the same strata on the opposite sides of the great European basin (assuming the primitive ranges of our own island as one of its borders, and those of the Alpine chains as the other), we shall find their level totally different.

The oolite, for instance, whose highest point with us is less than 1200 feet, attains a height of more than 4000 in the Jura chain, and in the mountains of the Tyrol has been observed by Mr. Buckland crowning some of the loftiest and most rugged summits of the Alps themselves. Again, if we compare the inclination of the strata at the edges of the basin, we shall find every thing but the supposed regular gradation, from a highly elevated to a horizontal position; on the contrary, we shall see the horizontal beds generally reposing at once upon the truncated edges of those which lie at very considerable angles; and in place of the general conformity or parallelism which ought to prevail between the several formations, we shall observe in many instances appearances of the greatest irregularity in this respect; and these irregularities will be found to increase in approaching those chains which are the most elevated.

But if we suppose, that during the regular and gradual subsidence of the level of the ocean, in the Wernerian system, the continents were elevated by mechanical forces acting in a series of great convulsions, we shall perhaps obtain a nearer approximation to agreement with the actual phenomena, as deduced from observation. If these convulsions resulted from volcanic agency, we have already seen that there is every reason to believe this cause to have acted with most violence in the earliest periods; and this will sufficiently account for the greater derangement of the earlier rocks.

That the valleys have been, in many instances, entirely excavated by the agency of powerful aqueous currents, and in all, greatly modified by the same cause, seems as completely proved as the nature of the case can possibly admit. The same diluvial agency that has excavated the valleys, appears also to have swept off the superior strata from extensive tracts which they once covered. The proofs of this are to be found in insulated hills, or *outliers* of those strata, placed at considerable distances from their continuous range, with which they have every appearance of having been once connected; in the abrupt and truncated escarpments which form the usual termination of the strata, and in the very great quantity of their *debris*, scattered frequently over tracts far distant from those where they still exist *in situ*. This stripping off the *superstrata* is appropriately termed *denudation*.

The most important agency of this kind appears to have been exerted at an early period, and subsequently to the consolidation of all the strata, by an inundation which must have swept over them universally, and covered the whole surface with their *debris* indiscriminately thrown together, forming the last great geological change to which the surface of our planet appears to have been exposed.

To this general covering of water-worn *debris* derived from all the strata, the name of *diluvium* has been given, from the consideration of that great and universal catastrophe to which it seems most properly assignable. By this name it is intended to distinguish it from the partial *debris* occasioned by causes still in operation; such as the slight wear produced by the present rivers, the more violent action of torrents, &c. To the latter the name of *alluvium* has lately been appropriated. It does not seem possible to assign any single and uniform direction to the currents which have driven the diluvial *debris* before them; but they appear in every instance to have flowed (which indeed must of necessity be the case with the currents of subsiding waters) as they were determined by the configuration of the adjoining country; from the mountains, that is, towards the lower hills and plains. As far as England is concerned, this principle will produce a general tendency to a direction from north-west towards south and east, greatly modified, however, by obvious local circumstances.

Another circumstance connected with the distribution of these travelled fragments is, that we often find them in masses of considerable size, accumulated in situations now separated by the intervention of deep valleys from the parent hills (if we may so speak), whence we know them to have been torn. This appears to be a demonstrative proof that these intervening valleys must have been excavated subsequently to the transportation of these blocks; for though we can readily conceive how the agency of violent currents may have driven these blocks down an inclined plane, or if the *vis a tergo* were sufficient, along a level surface, or even up a very slight and gradual acclivity, it is impossible to ascribe to them the Sisyphean labour of rolling rocky masses, sometimes of many tons in weight, up the face of abrupt and high escarpments. The attention of geologists was first directed to this phenomenon by the discoveries of Saussure, who noticed one of its most striking cases—the occurrence of massive fragments torn from the primitive chains of the Alps, scattered at high levels on the escarpment of the opposite calcareous and secondary chains of the Jura, although between the two points the deep valley containing the lake of Geneva is interposed. This phenomenon is one of very common occurrence. The Downs surrounding Bath (Hampton Down for example), though abruptly scarped, and surrounded by valleys more than 600 feet deep, have yet on their very summits flints transported from the distant chalk hills. The simplest explanation of the fact will be, that these fragments were transported by the first action of the currents, before they had effected the excavation of the valleys, now cutting off all communication with the native rocks whence they were derived.

The organic remains of land animals dispersed through this diluvial gravel must, with the greatest probability, be referred to the races extinguished by the great convulsion which formed that gravel; many of them are of species still inhabiting the countries where they are thus found; some of the species now inhabiting only other climates; and some few, of species and genera now entirely unknown.

To the same period we may ascribe the bones *of the same species with the above,* found in many caverns; but, in many of these instances, it is probable that some of the animals now found there previously inhabited as their dens. Professor Buckland appears to have proved satisfactorily, that this must have been the case in the remarkable instance of the cavern lately discovered near Kirby Moorside, Yorkshire. Here the remains found in the greatest abundance are those of hyænas; with these are mingled fragments of various animals, from the mammoth to the water-rat. All the bones present evident traces of having been mangled and gnawed; and the whole are buried in a sediment of mud subsequently incrusted over by stalactical depositions. Professor Buckland's explanation is, that this cavern was occupied by the hyænas; who, according to the known habits of these animals, partially devoured even the bones of their prey, and dragged them for that purpose to their dens; around their retreats, a similar *congeries* of mangled bones has been noticed by recent travellers. The proofs of these points, deduced from the circumstances of the cavern, the state of the bones, and the ascertained habits of the animals in question, appear to be decisive. The sediment in which the bones are imbedded, and the occurrence of the remains of the mammoths, and other species, only known (in these climates at least) in a fossil state, in the diluvial gravel, clearly refer their remains to the same era. Caverns containing bones of a similar class, the mammoth, the fossil species of a rhinoceros, &c. have been found near Swansea, at Hatton-hill (on the Mendip chain in Somersetshire), and near Plymouth.—*Rev. W. D. Conybeare, Introduction.*

The ancient history of the globe, which may be regarded as the *ultimate* object of geological researches, is undoubtedly one of the most curious subjects that can engage the attention of enlightened men. The lowest and most level parts of the earth, when penetrated to a very great depth, exhibit nothing but horizontal strata, composed of various substances, and containing almost all of them innumerable marine productions. Similar strata, with the same kind of productions, compose the hills even to a great height. Sometimes the shells are so numerous as to constitute the entire body of the stratum. They are almost every where in such a perfect state of preservation, that even the smallest of them retain their most delicate parts, their sharpest ridges, and tenderest processes. They are found in elevations far above the level of every part of the ocean, and in places to which the sea could not be conveyed by any presently existing cause. They are not merely enclosed in loose sand, but are often incrusted and penetrated on all sides by the hardest stones. Every part of the earth, every hemisphere, every continent, every island of any size, exhibits the same phenomenon. We are therefore forcibly led to believe, not only that the sea has at one period or another covered all our plains, but that it must have remained there for a long time, and in a state of tranquillity; which circumstance was necessary for the formation of deposites so extensive, so thick, in part so solid, and containing *exuviæ* so perfectly preserved. A nice and scrupulous comparison of the forms, contexture, and composition of these shells, and of those which still inhabit the sea, cannot detect the slightest difference between them. They have therefore once lived in the sea, and been deposited by it; the sea consequently must have rested in the places where the disposition has taken place. Hence it is evident, that the basin or reservoir containing the sea has undergone some change, either in extent, situation, or both.

The traces of revolutions become still more apparent and decisive when we ascend a little higher, and approach nearer to the foot of the great chain of mountains. There are still found many beds of shells; some of these are even larger and more solid; the shells are quite as numerous, and as entirely preserved; but they are not of the same species with those which were found in the less elevated regions. The strata which contain them are not so generally horizontal; they have various degrees of inclination, and are sometimes situated vertically. While in the plains and low hills it was necessary to dig deep in order to detect the succession of the strata, here we perceive them by means of the valleys, which time or violence has produced, and which disclose their edges to the eye of the observer.

Thus the sea, previous to the formation of the horizontal strata, had formed others, which by some means have been broken, lifted up, and overturned in a thousand ways. But the sea has not always deposited stony substances of the same kind. It has observed a regular succession as to the nature of its deposites; the more ancient the strata are, so much the more uniform and extensive are they; and the more recent they are, the more limited are they, and the more variation is observed in them at small distances. Thus the great catastrophes which have produced revolutions in the basins of the sea were preceded, accompanied, and followed by the changes in the nature of the fluid, and of the substances which it held in solution; and when the surface of the seas came to be divided by islands and projecting ridges, different changes took place in every separate basin.

These irruptions and retreats of the sea have neither been slow nor gradual: most of the catastrophes which have occasioned them have been sudden; and this is easily proved, especially with regard to the last of them, or the Mosaic deluge, the traces of which are very conspicuous. In the northern regions it has left the carcasses of some large quadrupeds, which the ice had arrested, and which are preserved even to the present day, with their skin, their hair, and their flesh. If they had not been frozen as soon as killed, they must have been quickly decomposed by putrefaction. But this perpetual frost could not have taken possession of the regions which these animals inhabited, except by the same cause which destroyed them: this cause must therefore have been as sudden as its effect. The two most remarkable phenomena of this kind, and which must for ever banish all idea of a slow and gradual revolution, are the rhinoceros, discovered in 1771 on the banks of the *Vilhoui*, and the elephant, recently found by Mr. Adams near the mouth of the *Sena*. This last retained its flesh and skin, on which was hair of two kinds; one short, fine, and crisped, resembling wool, and the other like bristles. The flesh was still in such high preservation, that it was eaten by dogs. Every part of the globe bears the impress of these great and terrible events so distinctly, that they must be visible to all who are qualified to read their history in the remains which they have left behind.

With this truly important branch of science we might, and perhaps ought to, connect the subject of mineralogy; but to enter upon it at large would exceed our limits; and from the following brief outline, together with what will be said under the article Chemistry, it is presumed the reader will obtain the information he may desire.

MINERALOGY is that science which treats of the solid and inanimate materials of which our globe consists; and these are usually arranged under four classes: the earthy, the saline, the inflammable, and the metallic, which are thus distinguished:

1. The earthy minerals compose the greater part of the crust of the earth, and generally form a covering to the rest. They are not remarkable for being heavy, brittle, or light coloured. They are little disposed to crystallize, are uninflammable in a low temperature, insipid, and without much smell.

2. The saline minerals are commonly moderately heavy, soft, sapid, and possess some degree of transparency.

3. The inflammable class of minerals is light, brittle, mostly opaque, of a yellow brown, or black colour, seldom crystallizes, and never feels cold.

4. Metallic minerals are characterized by being heavy, generally opaque, tough, malleable, cold, not easily inflamed, and by exhibiting a great variety of colours, of a peculiar lustre.

Under each of these classes are various genera, species, sub-species, and kinds, which will be noticed in order. Sometimes, as in the vegetable kingdom, we find a strict affinity between different species of minerals, and in that case they are said to belong to the same family; but in mineralogy, one class does not always blend with another in a chemical point of view, or furnish that beautiful gradation and almost imperceptible union which is to be traced in the other kingdoms of nature. As the external characters are of the first importance in facilitating our acquaintance with minerals, we shall briefly explain this subject, before we proceed to the classification of the different substances.

Of the external Characters of Minerals.

The external characters of minerals are either generic or specific. The generic characters are certain properties of minerals, without any reference to their differences, as colour, lustre, weight, &c.; and the differences between these properties form the specific characters.

Generic characters may be general or particular. In the first division are comprehended those that occur in all minerals; in the last those that are found only in particular classes of minerals.

The particular generic external characters are thus advantageously arranged:

1. Colour.

2. Cohesion of particles; distinguished into solid, friable, and fluid.

In solid minerals are to be regarded the external shape, the external surface, and the external lustre. When broken, the lustre of the fracture, the fracture itself, and the shape of the fragments, are to be noticed. In distinct concretions, regard must be paid to the shape of the concretions, their surface, their lustre, transparency, streak, and soiling. All these may be ascertained by the eye. By the touch, we may discover the hardness of minerals, their tenacity, frangibility, flexibility, their unctuosity, coldness, weight, and their adhesion to the tongue. By the ear we distinguish their sound, and by the smell and taste the qualities which these two senses indicate.

In friable minerals, external shape, lustre, aspect of particles, soiling, and degree of friability, are to be attended to.

In fluid minerals, the lustre, transparency, and fluidity, are principal objects to be regarded.

The specific external characters of minerals are founded on the distinctions and varieties of the two great generic divisions. And first, of colours, the names of which are derived from certain bodies in which they most generally occur, either in a natural or artificial state, or from different mixtures and compositions of both.

I. Colour.

1. White. This may be snow-white, reddish-white, yellowish-white, silver-white, greyish-white, greenish-white, milk-white, or tin-white.
2. Grey. Lead-grey, blueish-grey, pearl-grey, reddish-grey, smoke-grey, greenish-grey, yellowish-grey, steel-grey, and ash-grey.
3. Black. Greyish-black, brownish-black, dark-black, iron-black, greenish-black, and blueish-black.
4. Blue. Indigo-blue, Prussian-blue, lavender-blue, smalt-blue, sky-blue.
5. Green. Verdigris-green, celaden-green, mountain-green, emerald-green, leek-green, apple-green, grass-green, pistachio-green, asparagus-green, olive-green, blackish-green, canary-green.

6. Yellow. Sulphur-yellow, lemon-yellow, gold-yellow, bell-metal-yellow, straw-yellow, wine-yellow, Isabella-yellow, ochre-yellow, orange-yellow, honey-yellow, wax-yellow, and brass-yellow.

7. Red. Morning-red, hyacinth-red, brick-red, scarlet-red, copper-red, blood-red, carmine-red, cochineal-red, crimson-red, columbine-red, flesh-red, rose-red, peach-blossom-red, cherry-red, brownish-red.

8. Brown. Reddish-brown, clove-brown, hair-brown, yellowish-brown, tombac-brown, wood-brown, liver-brown, blackish-brown.

Besides these distinctions, colours may be clear, dark, light, or pale; they may have a tarnished appearance, a play, a changeability, an iridescence, an opalescence, a permanent alteration, and a delineation of figure or pattern, such as dotted, spotted, clouded, flamed, striped, veined, dendritic, or ruiniform.

II. Cohesion of Particles.

Minerals are divided into, 1. Solid, or such as have their parts coherent, and not easily moveable; 2. Friable, or that state of aggregation in which the particles may be overcome by simple pressure of the finger; and 3. Fluid, or such as consist of particles which alter their place in regard to each other by their own weight.

1. *Solid Minerals.*

External aspect has three things to be regarded: 1. The shape; 2. The surface; and 3. The lustre. The external shape again may be common, particular, regular, or extraneous; and hence arise the specific differences.

1. The common external shape may be massive; disseminated coarsely, minutely, or finely; in angular pieces, sharp cornered or blunt cornered; in grains, large, coarse, small, fine, angular, flat, round; in plates, thick or thin; in membranes or flakes, thick, thin, or very thin.

The particular external shape may be longish, as dentiform, filiform, capillary, reticulatic, dendritic, coralliform, stalactitic, cylindrical, tubiform, claviform, or fruticose; roundish, as globular, spherical, ovoidal, spheroidal, amygdaloidal, botryoidal, reniform, tuberose, or fused-like; flat, as specular, or in leaves; cavernous, as cellular, in various forms, with impressions, perforated, corroded, amorphous, or vesicular; entangled, as ramose, &c.

In the regular external shape or crystallization are to be regarded its genuineness, according to which it may be either true or supposititious; its shape, made up of planes, edges, angles, in which are to be observed the fundamental figure and its parts, the kind of fundamental figure, the varieties of each kind of fundamental figure, with their accidents and distinctions, and the alterations which the fundamental figure undergoes by truncation, by bevelment, by acumination, or by a division of the planes. There are a variety of figures under each of these subdivisions. It must be remarked also that the external shape may be extraneous, or derived from the animal and vegetable kingdoms, as in fossils and petrifications.

2. The external surface contains several varieties of distinctions. It may be uneven, granulated, rough, smooth, or streaked in various ways and directions.

3. The external lustre is the third generic external character, and is of much importance to be attended to. In this we have to consider the intensity of the lustre, whether it is splendent, shining, glistening, glimmering, or dull; next, the sort of lustre, whether metallic or common. The latter is distinguished into semimetallic, adamantine, pearly, resinous, and vitreous.

Aspect of the Fracture of Solid Minerals.

After the external aspect, the fracture forms no inconsiderable character in minerals. Its lustre may be determined as in the external lustre; but the fracture itself admits of great varieties. It may be compact splintery, coarsely splintery, finely splintery, even, conchoidal, uneven, earthy, hackly. If the fracture is fibrous, we are to consider the thickness of the fibres, if coarse or delicate; the direction of the fibres, if straight or curved; and the position of the fibres, if parallel or diverging.

In the radiated fracture we are to regard the breadth of the rays, their direction, their position, their passage or cleavage. In the foliated fracture, the size of the folia, their degree of perfection, their direction, position, aspect of their surface, passage or cleavage, and the number of cleavages, are to be noted.

The shape of the fragments may also be very various-regular, as cubic, rhomboidal, trapezoidal, &c. or irregular, as cuneiform, splintery, tabular, indeterminately angular.

Aspect of the distinct Concretions.

The shape of the distinct concretions forms very prominent external, characters. They may be granular, different in shape, or in magnitude; they may be lamellar, distinct, concretious, differing in the direction of the lamellæ, in the thickness, with regard to shape, and in the position.

The surface of the distinct concretions may be smooth, rough, streaked, or uneven; as for their lustre, it may be determined in the same manner as the external lustre.

General Aspect as to Transparency.

Minerals, as is well known, have different degrees of transparency, which may be considered among their external characters.—They may be transparent, semitransparent, translucent, translucent at the edges, or opaque.

The Streak.

The colour of this external character may be either similar or different. It is presented to us when a mineral is scraped with the point of a knife: and is similar, when the powder that is formed is of the same colour with the mineral, as in chalk; or dissimilar or different, as in cinnabar, orpiment, &c.

The Soiling or Colouring

Is ascertained by taking any mineral substance between the fingers, or drawing it across some other body. It may soil strongly, as in chalk; slightly, as in molybdena; or not at all, which is a quality belonging to most of the solid minerals. All the preceding external characters are recognized by the eye.

External Characters from the Touch.

These are eight in number, and are not destitute of utility to the mineralogical student. 1. Hardness; 2. Tenacity; 3. Frangibility; 4. Flexibility; 5. Adhesion to the tongue; 6. Unctuosity; 7. Coldness; 8. Weight.

Hardness may be tried by a capacity to resist the file, yielding a little to it, being semihard, soft, or very soft. Tenacity has different degrees, in substances being brittle, sectile or mild, or ductile. The frangibility consists in minerals being very difficultly frangible, difficultly frangible, easily frangible, or very easily frangible. The flexibility is proved by being simply flexible, elasticly flexible, commonly flexible, or inflexible. The adhesion to the tongue may be strongly adhesive, pretty strongly, weakly, very weakly, or not at all. Unctuosity may be meagre, rather greasy, greasy, or very greasy. Coldness is subdivided into cold, pretty cold, rather cold. Weight may be distinguished into swimming or supernatant, light, rather light, heavy, very heavy. The three last divisions from the touch are in the Wernerian system regarded as anomalous; but they seem properly to be classed under this head.

External Characters from the Sound or Hearing.

The different kinds of sound which occur in the mineral kingdom are, 1. A ringing sound, as in native arsenic and thin splinters of hornstone; 2. A grating sound, as in fresh-burnt clay; 3. A creaking sound, as that of natural amalgam.

2. *Friable Minerals.*

The external characters drawn from minerals of this class are derived, first, from the external shape, which may be massive, disseminated, thinly coating, spumous, or dendritic: secondly, from the lustre, regarded under its intensity, whether glimmering or dull, and its sort, whether common glimmering or metallic glimmering: thirdly, from the aspect of the particles, as being dusty or scaly: fourthly, from soiling or colouring, as strongly or lightly: and lastly, from the friability, which may be loose or cohering.

3. *Fluid Minerals.*

Of external characters drawn from fluid minerals, there are only two kinds, which include three varieties: 1. The lustre, which is either metallic, as in mercury, or resinous, as in rock oil. 2. The transparency, which is transparent, as in naphtha; turbid, as in mineral oil; or opaque, as in mercury. 3. The fluidity, which may be fluid, as in mercury, or viscid, as in mountain tar.

External Characters from the Smell.

These may be spontaneously emitted and described, as bituminous, faintly sulphureous, or faintly bitter; or they may be produced by breathing on, and yield a clay-like smell; or they may be excited by friction, and smell urinous, sulphureous, garlick-like, or empyreumatic.

External Character from the Taste.

This character prevails chiefly in the saline class, and it contains the following varieties: a sweetish taste, sweetish astringent, styptic, saltly bitter, saltly cooling, alkaline, or urinous.

NATURAL PHILOSOPHY.

THIS is a very wide and extremely interesting department of science. Its object is to observe and describe the phenomena of the material universe, for the purpose of discovering their causes, and the laws by which their motions are regulated. Most authors who have written on the subject have commenced with Mechanics, because on the right understanding of this branch much of all the other departments will be found to depend. In this treatise the same plan shall be followed.

CHAPTER IV

MECHANICS.

MECHANICS, from the Greek word μηχανη, is a term used to denote that branch of science which treats of the laws of the equilibrium and motion of solid bodies; of the forces by which bodies, whether animate or inanimate, may be made to act upon one another; and of the means by which these may be increased to almost any degree.

Sir Isaac Newton distinguishes this science into practical and rational mechanics.

Rational mechanics comprehends the whole theory of motion; shows, when the powers or forces are given, how to determine the motions that are produced by them; and conversely, when the phenomena of the motions are given, how to trace the powers or forces from which they arise.

Practical mechanics treats of what are denominated the mechanical powers, viz. the lever, balance, axis and wheel, pulley, wedge, screw, and the inclined plane.

The importance of these to society is incalculable: every machine whatever is composed of one or more of them, sometimes of several combined together.

In considering this science, it will be necessary at first to take some things for granted, that are not strictly true; and after the theory is established, to make the proper allowances for them.

1. That a small portion of the earth's surface, which is spherical, may be considered as a plane. 2. That all bodies be supposed to descend in lines parallel to each other; for though all bodies really tend to the centre of the earth, yet the distance from which they fall is comparatively so small, that their inclination towards each other is inconsiderable. 3. That all planes be considered as perfectly smooth; levers to be inflexible, and without thickness or weight; cords perfectly pliable; and machines without friction and inertia.

Three things are always to be considered in treating of mechanical engines; the weight to be raised, the power by which it is to be raised, and the instrument or engine by which this is to be effected.

The mechanical powers are generally reckoned six: the lever, the pulley, the wheel and axis, the inclined plane, the wedge, and the screw.

These perhaps may be reduced to two; for the pulley and wheel are only assemblages of levers, and the wedge and screw are inclined planes.

The Lever.

The *lever* is the simplest of all machines; and is only a straight bar of iron, wood, or other material, supported on, and moveable round, a prop called the fulcrum.

In the lever there are three circumstances to be principally attended to. 1. The fulcrum, or prop, by which it is supported, or on which it turns as an axis, or centre of motion: 2. The power to raise and support the weight: 3. The resistance or weight to be raised or sustained.

The points of suspension are those points where the weights really are, or from which they hang freely. The power and the weight are always supposed to act at right angles to the lever, except it is otherwise expressed.

The lever is distinguished into three sorts, according to the different situations of the fulcrum or prop, and the power, with respect to each other. 1. When the prop is placed between the power and the weight. 2. When the prop is at one end of the lever, the power at the other, and the weight between them. 3. When the prop is at one end, the weight at the other, and the power applied between them.

The lever of the first kind is principally used for loosening large stones; or to raise great weights to small heights, in order to get ropes under them, or other means of raising them to still greater heights; it is the most common species of lever.

ABC, plate II. fig. 1, is this lever, in which B is the fulcrum, A the end at which the power is applied, and C the end where the weight acts.

To find when an equilibrium will take place between the power and the weight, in this as well as in every other species of lever, it is necessary to recollect that when the momenta, or quantities of force, in two bodies are equal, they will balance each other. Now let us consider when this will take place in the lever. Suppose the lever AB, fig. 2, to be turned on its axis, or fulcrum, so as to come into the situation DC; as the end D is farthest from the centre of motion, and as it has moved through the arch AD in the same time as the end B moved through the arch BC, it is evident that the velocity of AB must have been greater than that of B. But the momenta being the products of the quantities of matter, multiplied into the velocities, the greater the velocity, the less the quantity of matter need be to get the same product. Therefore, as the velocity of A is the greatest, it will require less matter to produce an equilibrium than B.

Let us next see how much more weight B will require than A to balance it. As the radii of circles are in proportion to their circumferences, they are also proportionate to similar parts of them; therefore, as the arches AD, CB, are similar, the radius or arm DE bears the same proportion to EC that the arch AD bears to CB. But the arches AD and CB represent the velocities of the ends of the lever, because they are the spaces which they moved over in the same time; therefore the arms DE and EC may also represent these velocities. It is evident then, that an equilibrium will take place when the length of the arm AE multiplied into the power A, shall equal EB multiplied into the weight B; and consequently, that the shorter EB is, the greater must be the weight B; that is, the power and the weight must be to each other inversely as their distances from the fulcrum.

Thus suppose AE, the distance of the power from the prop, to be twenty inches, and EB, the distance of the weight from the prop, to be eight inches, also the weight to be raised at B to be five pounds, then the power to be applied at A must be two pounds; because the distance of the weight from the fulcrum eight, multiplied into the weight five, makes 40; therefore 20, the distance of the power from the prop, must be multiplied by two to get an equal product, which will produce an equilibrium.

The second kind of lever, when the weight is between the fulcrum and the power, is represented by fig. 3, in which A is the fulcrum, B the weight, and C the power. The advantage gained by this lever, as in the first, is as great as the distance of the power from the prop exceeds the distance of the weight from it. Thus if the point *a*, on which the power acts, is seven times as far from A as the point *b*, on which the weight acts, then one pound applied at C will raise seven pounds at B. To this kind of lever may be reduced oars, rudders of ships, doors turning upon hinges, cutting-knives which are fixed at the point, &c. If in this lever we suppose the power and the weight to change places, so that the power may be between the weight and the prop, it will become a lever of the third kind; in which, that there may be a balance between the power and the weight, the intensity of the power must exceed the intensity of the weight just as much as the distance of the weight from the prop exceeds the distance of the power. Thus let E, fig. 4, be the prop of the lever EF, and W a weight of one pound, placed three times as far from the prop as the power P acts at F, by the cord going over the fixed pulley D: in this case the power must be equal to three pounds, in order to support the weight of one pound.

To this sort of lever are generally referred the bones of a man's arm; for when he lifts a weight by the hand, the muscle that exerts its force to raise that weight is fixed to the bone about one-tenth part as far below the elbow as the hand is. And the elbow being the centre round which the lower part of the arm turns, the muscle must therefore exert a force ten times as great as the weight that is raised.

What is called the hammer-lever differs in nothing but its form from a lever of the first kind. Its name is derived from its use, that of drawing a nail out of wood by a hammer.

Let A C B, fig. 5, represent a lever of this sort, bent at C, which is its prop, or centre of motion. P is a power acting upon the longer arm AC, at A, by means of the cord DA going over the pulley D; and W is a weight or resistance acting upon the end B of the shorter arm CB. If the power is to the weight as CB is to CA, they are in equilibrio; thus, suppose W to be five pounds, acting at the distance of one foot from the centre of motion C, and P to be one pound, acting at A, five feet from the centre C; the power and weight will just balance each other.

If several levers are combined together in such a manner, as that a weight being appended to the first lever may be supported by a power applied to the last, as in fig. 6, (which consists of three levers of the first kind, and is so contrived, that a power applied at the point L, of the lever C, may sustain a weight at the point S of the lever A), the power must here be to the weight, in a ratio, or proportion, compounded of the several ratios which those powers that can sustain the weight by the help of each lever, when used singly and apart from the rest, have to the weight. For instance: if the power which can sustain the weight P by the help of the lever A, is to the weight as 1 to 5; and if the power which can sustain the same weight by the lever B alone, is to the weight as 1 to 4; and if the power which could sustain the same weight by the lever C is to the weight as 1 to 5; then the power which will sustain the weight by the help of the three levers joined together, will be to the weight in a proportion consisting of the several proportions multiplied together, of 1 to 5, 1 to 4, and 1 to 5; that is, of 1 to 100. For since, in the lever A, a power equal to one-fifth of the weight P pressing down the lever at L, is sufficient to balance the weight; and since it is the same thing whether that power is applied to the lever A at L, or the lever B at S, the point S bearing on the point L; a power equal to one-fifth of the weight P, being applied to the point S of the lever B, will support the weight; but one-fourth of the same power being applied to the point L of the lever B, and pushing the same upward, will as effectually depress the point S of the same levor, as if the whole power was applied at S; consequently, a power equal to one-fourth of one-fifth, that is, one-twentieth of the weight P, being applied to the point L of the lever B, and pushing up the same, will support the weight; in like manner, it matters not whether that force is applied to the point L of the lever B, or to the point S of the lever C, since, if S be raised, L, which rests on it, must be raised also; but one-fifth of the power applied at the point L of the lever C, and pressing it downwards, will as effectually raise the point S of the same lever, as if the whole power were applied at S, and pushed up the same; consequently a power equal to one-fifth of one-twentieth, that is, one-hundredth part of the weight P, being applied to the point L of the lever C, will balance the weight at the point S of the lever A.

The balance, an instrument of very extensive use in comparing the weights of bodies, is a lever of the first kind, whose arms are of equal length. The points from which the weights are suspended being equally distant from the centre of motion, will move with equal velocity; consequently, if equal weights are applied, the momenta will be equal, and the balance will remain in equilibrio.

In order to have a balance as perfect as possible, it is necessary to attend to the following circumstances: 1. The arms of the beam ought to be exactly equal, both as to weight and length. 2. The points from which the scales are suspended should be in a right line, passing through the centre of gravity of the beam; for by this the weights will act directly against each other, and no part of either will be lost on account of any oblique direction. 3. In a balance, therefore, the fulcrum ought always to be placed a little above the centre of gravity. Its vibrations will be quicker, and its horizontal tendency stronger, the lower the centre of gravity, and the less the weight upon the points of suspension. 4. The friction of the beam upon the axis ought to be as little as possible; because should the friction be great, it will require a considerable force to overcome it. The axis of motion should be formed with an edge like a knife, and made very hard; these edges are at first made sharp, and then rounded with a fine hone, or piece of buff leather, which causes a sufficient bluntness, or rolling edge. 5. The pivots which form the axis or fulcrum should be in a straight line, and at right angles to the beam. 6. The arms should be as long as possible, relatively to their thickness, and the purposes for which they are intended; as the longer they are, the more sensible is the balance. They should also be made as stiff and inflexible as possible; for if the beam is too weak, it will bend, and become untrue. 7. The rings, or the piece on which the axis bears, should be hard and well polished, parallel to each other, and of an oval form, that the axis may always keep its proper bearing, or remain always at the lowest point.

The statera, or Roman steel-yard, is a lever of the first kind, and is used for finding the weights of different bodies, by one single weight placed at different distances from the prop or centre of motion D, fig. 7. For the shorter arm DG is of such a weight as exactly to counterpoise the longer arm DX. If this arm is divided into as many equal parts as it will contain, each equal to GD, the single weight P (which we may suppose to be one pound) will serve for weighing any thing as heavy as itself, or as many times heavier as there are divisions in the arm DX, or any quantity between its own weight and that quantity. As for example, if P is one pound and placed at the first division I in the arm DX, it will balance one pound in the scale at W: if it is removed to the second division at 2, it will balance two pounds in the scale; if to the third, three pounds; and so on to the end of the arm DX. If any of these integral divisions be subdivided into as many equal parts as a pound contains ounces, and the weight P be placed at any of these subdivisions, so as to counterpoise what is in the scale, the pounds and odd ounces therein will by that means be ascertained.

The Wheel and Axle.

The wheel and axle is a machine much used, and is made in a variety of forms. It consists of a wheel with an axle fixed to it, so as to turn round with it; the power being applied at the circumference of the wheel, and the weight to be raised is fastened to a rope which coils round the axle.

AB, fig. 9, plate III. is a wheel and CD an axle fixed to it, and which moves round with it. If the rope which goes round the wheel is pulled, and the wheel turned once round, it is evident that as much rope will be drawn off as the circumference of the wheel; but while the wheel turns once round, the axle turns once round; and consequently the rope by which the weight is suspended will wind once round the axis, and the weight will be raised through a space equal to the circumference of the axis.

The velocity of the power, therefore, will be to that of the weight, as the circumference of the wheel to that of the axis.

That the power and the weight may be in equilibrio, therefore, the power must be to the weight as the circumference of the wheel to that of the axis.

It is proved by geometry that the circumferences of different circles bear the same proportion to each other as their respective diameters do; consequently the power is to the weight as the diameter also of the axis to that of the wheel.

Thus, suppose the diameter of the wheel to be eight inches, and the diameter of the axis to be one inch; then one ounce acting as the power P will balance eight ounces as a weight W; and a small additional force will cause the wheel to turn with its axis, and raise the weight; and for every inch which the weight rises, the power will fall eight inches.

The wheel and axis may be considered as a kind of perpetual lever, of which the fulcrum is the centre of the axis, and the long and short arms are the diameter of the wheel and the diameter of the axis.

From this it is evident, that the larger the wheel, and the smaller the axis, the stronger is the power of this machine; but then the weight must rise slower in proportion.

A capstan is a cylinder of wood, with holes in it, into which are put bars, or levers, to turn it round; these are like the spokes of a wheel without the rim. Sometimes the axis is turned by a winch fastened to it, which in this respect serves for a wheel; and is more powerful in proportion to the largeness of the circle it describes, compared with the diameter of the axle.

When the parts of the axis differ in thickness, and weights are suspended at the different parts, they may be sustained by one and the same power applied to the circumference of the wheel: provided the product arising from the multiplication of the power into the diameter of the wheel, is equal to the sum of the products arising from the multiplication of the several weights into the diameters of those parts of the axis from which they are suspended.

In considering the theory of the wheel and axle, we have supposed the rope that goes round the axle to have no sensible thickness; but as in practice this cannot be the case, if it is a thick rope, or if there are several folds of it round the axis, you must measure to the middle of the outside rope, to obtain the diameter of the axis, for the distance of the weight from the centre is increased by the coiling up of the rope.

If teeth are cut in the circumference of a wheel, and if they work in the teeth of another wheel of the same size, as fig. 10, plate II. it is evident that both the wheels will revolve in the same time; and the weight appended to the axle of the wheel B, will be raised in the same time as if the axle had been fixed to the wheel A. But if the teeth of the second wheel are made to work in teeth made in the axle of the first, as at fig. 11, as every part of the circumference of the second wheel is applied successively to the circumference of the axle of the first, and as the former is much greater than the latter, it is evident that the first wheel must go round as many times more than the second, as the circumference of the second wheel exceeds that of the first axle.

In order to a balance here, the power must be to the weight, as the product of the circumferences, or diameters of the two axles multiplied together, is to the circumferences or diameters of the two wheels. This will become sufficiently clear, if it is considered as a compound lever, which was explained above. Instead of a combination of two wheels, three or four wheels may work in each other, or any number; and by thus increasing the number of wheels, or by proportioning the wheels to the axis, any degree of power may be acquired.

To this sort of engine belong all cranes for raising great weights, and in this case the wheel may have cogs all round it, instead of handles; and a small trundle may be made to work in the cogs, and be turned by a winch, which will make the power of the engine to exceed the power of the man who works it, as much as the number of revolutions of the winch exceeds those of the axle CD, fig. 9, when multiplied by the excess of the length of the winch above the length of the semidiameter of the axle, added to the semidiameter of the rope K, by which the weight is drawn up. Thus, suppose the diameter of the rope and axle taken together to be 13 inches, and consequently half their diameter to be 6½ inches, so that the weight W will hang at 6½ inches perpendicular distance from below the centre of the axle. Now let us suppose the wheel AB, which is fixed on the axle, to have 80 cogs, and to be turned by means of a winch 6½ inches long, fixed on the axle of a trundle of eight staves, or rounds, working in the cogs of the wheel; here it is plain that the winch and trundle would make ten revolutions for one of the wheel AB, and its axis CD, on which the rope K winds in raising the weight W: and the winch being no longer than the sum of the semidiameters of the great axle and rope, the trundle could have no more power on the wheel than a man could have by pulling it round by the edge, because the winch would have no greater velocity than the edge of the wheel has, which we here suppose to be ten times as great as the velocity of the rising weight: so that, in this case, the power gained will be as 10 is to 1. But if the length of the winch is 13 inches, the power gained will be as 20 to 1; if 19½ inches (which is long enough for any man to work by), the power gained will be as 30 to 1; that is, a man could raise 30 times as much by such an engine, as he could do by his natural strength without it, because the velocity of the handle of the winch would be 30 times as great as the velocity of the rising weight; the absolute force of any engine being in the proportion of the velocity of the power, to the velocity of the weight raised by it. But then, just as much power or advantage as is gained by the engine, so much time is lost in working it, which is common in all mechanical cases whatever.

In this sort of machines, it is requisite to have a ratchet wheel on the end of the axle C, with a catch to fall into its teeth; which will at any time support the weight, and keep it from descending, if the person who turns the handle should quit his hold while the weight is rising. By this means, the danger is prevented which might otherwise happen by the running down of the weight when left at liberty.

The Pulley.

The pulley is a small wheel turning on an axis, with a drawing rope passing over it: the small wheel is usually called a sheeve, and is so fixed in a box, or block, as to be moveable round a pin passing through its centre.

Pulleys are of two kinds:—1. Fixed, which do not move out of their places; 2. Moveable, which rise and fall with the weight.

When a pulley is fixed, as fig. 12, two equal weights suspended to the ends of a rope passing over it will balance each other, for they stretch the rope equally, and if either of them is pulled down through any given space, the other will rise through an equal space in the same time; and consequently, as the velocities of both are equal, they must balance each other. This kind of pulley, therefore, gives no mechanical advantage; so that you can raise no greater weight by it than you could do by your natural strength. Its use consists in changing the direction of the power, and sometimes enabling it to be applied with more convenience. By it a man may raise a weight to any point, without moving from the place he is in; whereas, otherwise, he would have been obliged to ascend with the weight: it also enables several men together to apply their strength to the weight by means of the rope.

The moveable pulley represented at A, fig. 13, is fixed to the weight W, and rises and falls with it. In comparing this to a lever, the fulcrum must be considered as at A; the weight acts upon the centre, and the power is applied at the extremity of the lever D. The power, therefore, being twice as far from the fulcrum as the weight is, the proportion between the power and weight, in order to balance each other, must be as 1 to 2. Whence it appears, that the use of this pulley doubles the power, and that a man may *raise twice as much by it as by his strength alone. Or it may be considered in this way. Every moveable* pulley hangs by two ropes equally stretched, and which must, consequently, bear equal parts of the weight: but the rope AB being made fast at B, half the weight is sustained by it; and the other part of the rope, to which the power is applied, has but half the weight to support: consequently the advantage gained by this pulley is as 2 to 1.

When the upper and fixed block contains two pulleys, which only turn upon their axis, and the lower moveable block contains also two, which not only turn on their axis, but rise with the weight W, fig. 14, the advantage gained is as 4 to 1. For each lower pulley will be acted upon by an equal part of the weight; and because in each pulley that moves with the weight a double increase of power is gained, the force by which W may be sustained will be equal to half the weight divided by the number of lower pulleys; that is, as twice the number of lower pulleys is to 1, so is the weight suspended to the power.

But if the extremity C, fig. 15, is fixed to the lower block, it will sustain half as much as a pulley; consequently here the rule will be, as twice the number of pulleys, adding unity, is to one, so is the weight to the power.

These rules hold good, whatever may be the number of pulleys in the blocks.

If, instead of one rope going round all the pulleys, the rope belonging to each pulley is made fast at the top, as in fig. 16, a different proportion between the power and the weight will take place. Here it is evident that each pulley doubles the power; thus, if there are two pulleys, the power will sustain four times the weight.

Fig. 8 is the concentric pulley invented by Mr. James White. O, R, are two brass blocks, in which grooves are cut; and round these a cord is passed, by which means they answer the purpose of so many distinct pulleys. The advantage gained is found by doubling the number of grooves in the lower block.

It is common to place all the pulleys in each block on the same pin, by the side of each other, as in fig.

17; but the advantage and rule for the power are the same here as in figs. 14 and 15.

A pair of blocks with the rope fastened round them is commonly called a tackle.

The Inclined Plane.

This mechanical power is of very great use in rolling up heavy bodies, such as casks, wheelbarrows, &c. It is formed by placing boards or earth in a sloping direction.

The force with which a body descends upon an inclined plane is to the force of its absolute gravity, by which it would descend perpendicularly in free space, as the height of the plane is to its length. For suppose the plane AB, fig. 19, to be parallel to the horizon, the cylinder C will keep at rest on any part of the plane where it is laid. If the plane is placed perpendicularly, as AB, fig. 20, the cylinder C will descend with its whole force of gravity, because the plane contributes nothing to its support or hindrance; and therefore it would require a power equal to its whole weight to keep it from descending.

Let AB, fig. 21, be a plane parallel to the horizon, and AD a plane inclined to it; and suppose the whole length AD to be three times as great as the perpendicular DB. In this case, the cylinder E will be supported upon the plane DA, and kept from rolling, by a power equal to a third part of the weight of the cylinder; therefore a weight may be rolled up this inclined plane by a third part of the power which would be sufficient to draw it up by the side of an upright wall.

It must also be evident, that the less the angle of elevation, or the gentler the ascent is, the greater will be the weight which a given power can draw up; for the steeper the inclined plane is, the less does it support of the weight; and the greater the tendency which the weight has to roll, consequently the more difficult for the power to support it: the advantage gained by this mechanical power, therefore, is as great as its length exceeds its perpendicular height. To the inclined plane may be reduced all hatchets, chisels, and other edge-tools.

The Wedge

Is the fifth mechanical power or machine; it may be considered as two equally inclined planes, joined together at their bases: then DG, fig. 21, is the whole thickness of the wedge at its back ABGD, where the power is applied; EF is the depth or height of the wedge; BF the length of one of its sides; and OF is its sharp edge, which is entered into the wood intended to be split, by the force of a hammer or mallet striking perpendicularly on its back. Thus AB, fig. 23, is a wedge driven into the cleft CED of the wood FG.

When the wood does not cleave at any distance before the wedge, there will be an equilibrium between the power impelling the wedge downward, and the resistance of the wood acting against the two sides of the wedge, when the power is to the resistance as half the thickness of the wedge at its back is to the length of either of its sides; because the resistance then acts in a direction perpendicular to the sides of the wedge. But when the resistance on each side acts parallel to the back, the power that balances the resistances on both sides will be, as the length of the whole back of the wedge is to double its perpendicular height.

When the wood cleaves at any distance before the wedge (as it generally does), the power impelling the wedge will not be to the resistance of the wood as the length on the back of the wedge is to the length of both its sides; but as half the length of the back is to the length of either side of the cleft, estimated from the top or acting part of the wedge. For, if we suppose the wedge to be lengthened down from the top CE to the bottom of the cleft at D, the same proportion will hold; namely, that the power will be to the resistance as half the length of the back of the wedge is to the length of either of its sides: or, which amounts to the same thing, as the whole length of the back is to the length of both the sides. The wedge is a very great mechanical power, since not only wood, but even rocks, can be split by it; which it would be impossible to effect by the lever, wheel and axle, or pulley; for the force of the blow or stroke shakes the coherent parts, and thereby makes them separate more easily.

The Screw

The screw is the sixth and last mechanical power, but cannot properly be called a simple machine, because it is never used without the application of a lever or winch to assist in turning it; and then it becomes a compound engine of a very great force, either in pressing the parts of bodies closer together, or in raising great weights. It may be conceived to be made by cutting a piece of paper, ABC, fig. 24, into the form of an inclined plane, or half wedge; and then wrapping it round a cylinder, fig. 25, the edge of the paper AC, will form a spiral line round the cylinder, which will give the thread of the screw. It being evident that the winch must turn the cylinder once round, before the weight of resistance can be moved from one spiral winding to another, therefore as much as the circumference of a circle described by the handle of the winch is greater than the interval or distance between the spirals, so much is the force of the screw. Thus supposing the distance of the spirals to be half an inch, and the length of the winch twelve inches, the circle described by the handle of the winch where the power acts will be 76 inches nearly, or about 152 inches, and consequently 152 times as great as the distance between the spirals: and therefore a power at the handle, the intensity of which is equal to no more than a single pound, will balance 152 pounds acting against the screw; and as much additional force as is sufficient to overcome the friction will raise the 152 pounds; and the velocity of the power will be to the velocity of the weight as 152 to 1. Hence it appears that the longer the winch is, and the nearer the spirals are to one another, so much the greater the force of the screw.

A very considerable degree of friction always acts against the power in a screw, but this is fully compensated by other advantages; for on this account the screw continues to sustain a weight, even after the power is removed, or ceases to act, and presses upon the body against which it is driven. Hence the screw will sustain very great weights; insomuch that several screws, properly applied, would support a large building, whilst the foundation was mending, or renewed.

Of Compound Machines.

Though it is evident from the principles delivered above, that any one of the mechanical powers is capable of overcoming the greatest possible resistance in theory; yet in practice, if used singly for producing very great effects, they would be frequently so unwieldy and unmanageable, as to render it impossible to apply them. For this reason, it is generally found more advantageous to combine them together; by which means the power is more easily applied, and many other advantages are obtained. In all machines, simple as well as compound, what is gained in power is lost in time. Suppose that a man, by a fixed pulley, raises a beam to the top of a house in two minutes, it is clear that he will be able to raise six beams in twelve minutes; but by means of a tackle with three lower pulleys he will raise all at once, with the same ease as he before raised one; but then he will be six times as long about it, that is, twelve minutes: thus the work is performed in the same time, whether the mechanical power is used or not. But the convenience gained by the power is very great; for if the six beams are joined in one, they may be raised by the tackle, though it would be impossible to move them by the unassisted strength of one man.

No real gain of force is, therefore, obtained by mechanical contrivances; on the contrary, from friction, and other causes, force is always lost; but by machines we are able to give a more convenient direction to the moving power, and to apply its action at some distance from the body to be moved, which is a circumstance of great importance. By machines also, we can so modify the energy of the moving power, as to obtain effects which it could not produce without this modification.

In machines composed of several of the mechanical powers, the power will be to the weight, when they are in equilibrio, in a proportion formed by the multiplication of the several proportions which the power bears to the weight in every separate mechanical power of which the machine consists.

In contriving machines, simplicity ought particularly to be attended to; for a complicated machine is not only more expensive, and more apt to be out of order, but there is also a greater degree of friction, in proportion to the number of rubbing parts.

Whatever may be the construction of a machine, its power will always be in proportion to the velocity of the power to the weight; and so that this is obtained in the greatest degree that circumstances will admit, then the fewer parts the better.

It is evident, from the principles already laid down, that the velocity of a wheel is to that of a pinion, or smaller wheel which is driven by it, in proportion to the diameter, circumference, or number of teeth in the pinion to that of the wheel.

Hence, if you have any number of wheels acting on so many pinions, you must divide the product of the teeth in the wheels by those in the pinions; and the quotient will give the number of turns of the last pinion in one turn of the first wheel.

Any number of teeth on the wheels and pinions having the same ratio, will give the same number of revolutions to an axis: thus, $\frac{64}{10} \times \frac{50}{5} \times \frac{36}{6} = \frac{115200}{480} = 240$, as before. It therefore depends upon the skill of the engineer or mechanic, to determine what numbers will best suit his design.

It is evident that the same motion may be performed either by one wheel and pinion, or by many wheels and pinions, provided the number of turns of all the wheels bear the same proportion to all the pinions which that one wheel bears to its pinion.

The power of a machine is not at all altered by the size of the wheels, provided the proportions to each other are the same.

The Application of Animal Strength as a moving Power in Machinery.

A horse draws with the greatest advantage when the line of draught is not level with his breast, but inclines upwards, making a small angle with the horizontal plane.

A horse drawing weight over a single pulley can draw 200lb. for eight hours a day, and walking at the rate of $2\frac{1}{2}$ miles in an hour, which is about $3\frac{1}{2}$ feet in a second; and if the same horse be made to draw 240lb. he can work but six hours a day, and cannot go quite so fast.

When a horse draws in a mill, or gin of any kind, great care should be taken that the horse-walk or circle in which he moves be large enough in diameter, otherwise the horse cannot exert all his strength; for, in a small circle, the tangent (in which the horse draws) deviates more from the circle in which the horse is obliged to go than in a larger circle. The horse-walk should not be less than 40 feet in diameter, when there is room for it. In a walk of 19 feet diameter, it has been calculated that a horse loses two-fifths of his strength. The worst way of applying the force of a horse is to make him carry or draw up a hill; for if the hill is steep, three men will do more than a horse. As a horse, from the structure of his body, can exert most strength in drawing almost horizontally in a straight line, a man exerts the least strength that way.

A man turning a horizontal windlass by a handle, or winch, should not have above 30lb. weight acting against him, if he is to work ten hours a day, and raise the weight at the rate of three feet and a half in a second. This supposes, however, that the semidiameter of the windlass is equal to the distance from the centre to the elbow of the handle; for if there is a mechanical advantage, as there usually is, by having the diameter of the axle, on which the rope winds, four or five times less than the diameter of the circle described by the hand, then may the weight (taking in also the resistance, on account of the friction and stiffness of the rope) be four or five times greater than 30lb. that is, so much as it rises slower than the hand moves.

The preceding principles being well understood, the student will find little difficulty in making any calculations connected with the construction of machinery.

It is only necessary to add a few observations respecting the nature and use of the pendulum.

By a pendulum in mechanics is meant a heavy body so suspended that it may vibrate, or swing backwards and forwards, about a fixed point, by the action of gravity.

The vibrations of a pendulum are called its oscillations. A pendulum, therefore, is any body, B, fig. 26, suspended upon, and moving about a fixed point, A, as a centre. The nature of a pendulum consists in the following particulars: 1. The times of the vibrations of a pendulum, in very small arches, are all equal. 2. The velocity of the bob, in the lowest point, will be nearly as the length of the chord of the arch which it describes in the descent. 3. The times of vibration in different pendulums, A B, A C, are as the square roots of the times of their vibrations. 4. The time of one vibration is to the time of the descent, through half the length of the pendulum, as the circumference of a circle to its diameter. 5. Whence the length of a pendulum, vibrating seconds, will be found 39·2 inches nearly; and that of a half-second pendulum 9·8 inches. 6. A uniform homogeneous body, B G, fig. 27, has a rod, staff, &c. which is one-third part longer than a pendulum A D, and will vibrate in the same time with it. See fig. 28.

From these properties of the pendulum we may discern its use as an universal chronometer, or regulator of time, as it is used in clocks, and such-like machines.

By this instrument also we can measure the distance of a ship, by measuring the interval of time between the fire and the sound of the gun: also the distance of a cloud, by numbering the seconds, or half-seconds, between the lightning and thunder; thus, suppose between the lightning and thunder we number 10 seconds; then, because sound passes through 1142 feet in one second, we have the distance of the cloud equal to 11·420 feet. Again, the height of any room, or other object, may be measured by a pendulum vibrating from the top thereof. Thus, suppose a pendulum from the height of a room vibrates once in three seconds; then say, as 1 is to the square of 3, viz. 9, so is 39·2 to 352·8 feet, the height required. Lastly, by the pendulum we discover the different force of gravity on different parts of the earth's surface, and thence the true figure of the earth.

The following is a brief description of what is commonly termed the *gridiron* pendulum:—Instead of one rod, this pendulum is composed of any convenient odd number of rods, as five, seven, or nine: being so connected, that the effect of one set of them counteracts that of the other set; and therefore, if they are properly adjusted to each other, the centres of suspension and oscillation will always be equidistant.

Fig. 29 represents a gridiron pendulum composed of nine rods, steel and brass alternately.

The two outer rods, A B, C D, which are of steel, are fastened to the cross pieces A C, B D, by means of pins. The next two rods, E F, G H, are of brass, and are fastened to the lower bar B D, and to the second upper bar E G. The two following rods are of steel, and are fastened to the cross bars E G and I K. The two rods adjacent to the central rod being of brass, are fastened to the cross pieces I K and L M; and the central rod to which the ball of the pendulum is attached is suspended from the cross piece L M, and passes freely through a perforation in each of the cross bars I K, B D. From this disposition of the rods, it is evident that, by the expansion of the extreme rods, the cross piece B D, and the two rods attached to it, will descend: but since these rods are expanded by the same heat, the cross piece E G will consequently be raised, and therefore also the two next rods; but because these rods are also expanded, the cross bar I H will descend: and by the expansion of the two next rods, the piece L M will be raised a quantity sufficient to counteract the expansion of the central rod. Whence it is obvious, that the effect of the steel rods is to increase the length of the pendulum in hot weather, and to diminish it in cold weather, and that the brass rods have a contrary effect upon the pendulum. The effect of the brass rods must, however, be equivalent not only to that of the steel rods, but also to the part above the frame and spring, which connects it with the clock, and to that part between the lower part of the frame and the centre of the ball.

The gridiron pendulum was the invention of Mr. John Harrison, a very ingenious artist, and celebrated for his invention of the watch for finding the difference of longitude at sea, about the year 1725, and of several other time-keepers and watches since that time; for all which he received the parliamentary reward of between £20,000 and £30,000.

CHAPTER V.

HYDROSTATICS.

THE science of hydrostatics has for its object the examination of the mechanical laws which regulate the motions, pressure, gravitation, and equilibrium of inelastic fluids, and also their effect on those bodies which float upon, or are immersed in them.

Archimedes, among the ancients, accomplished the most remarkable discoveries in this science. He is honoured even at this day, as the inventor of the ingenious hydrostatic process by which the purity or baseness of a crown of gold was ascertained. Among the moderns we are indebted to Galileo, Torricelli, Descartes, Pascal, Guglielmini, and Mariotte, for the best information on this subject; and by their experiments (which are as curious as they are decisive) we are instructed in what we may expect or fear from the power of fluids violently acted upon by the principle of gravity, and in what manner, and upon what principles we may employ, for the use of man, the hydraulic machines.

The propensity which bodies have of approaching towards the earth is the only cause of what we term weight or gravity, and it is by the continual efforts which they make to obey that law that they press upon every obstacle which impedes their progress. As fluids, like solid bodies, are impelled by their gravity, so in this case they press upon every object which opposes their fall; but from their nature they press in a different manner from solid bodies.

Fluids are substances, the component parts of which are moveable among themselves, having scarcely any cohesion one with another, and moving independently of each other. The proper objects of the hydrostatic science are those fluids which, in common language, are termed liquids, or those which alwavs present to us a plain surface, level or parallel to the horizon.

All liquid substances are not equally so. Water and oil both flow when the vessels, which contain them, are either overturned or broken; but the effusion of oil is slower than that of water, because the particles of oil have more cohesion among themselves. The most singular effects in hydrostatics principally depend, perhaps, upon the extreme minuteness of the particles of fluids, but at least upon their great mobility.

To preserve order in the consideration of this subject, it will be necessary to divide the objects of our inquiry into three branches. In the first place, we shall consider in what manner the principle of gravity acts on the particles of fluids, and the phenomena which it produces in the fluids themselves; as well as their action against the sides, the bottoms, and tops of the vessels in which they are contained: secondly, in what manner fluids of different densities act upon each other: and thirdly, the action of fluids on bodies immersed in them.

In pursuing the first object of this inquiry, it may be established as an axiom,

I. That the parts of the same fluid act, with respect to their weight or pressure, independently of each other.

This property arises from their having scarcely any cohesion among themselves. It is otherwise with solid bodies; their several parts adhering together, they press in one common mass; hence the falling of solid bodies is productive of a different effect from that of liquids. We dread the falling of a pound of ice upon our heads, while we are much more indifferent concerning that of a pound of water. The latter, in its descent, is divided by the resistance of the air, by which some of its parts are retarded more than others; and by being thus divided it requires a larger surface, which abates its effect. On the contrary, a solid body falls upon a small space, which receives its whole force.

It follows from this principle, that if an aperture is made at the bottom of a vessel full of any fluid, in order to prevent the flowing out of the liquor, it is only necessary to counteract the weight of that column of fluid which has the aperture for its base, and that to counteract that weight it is the same whether the vessel is full of liquor, or whether it contains only a column, the base of which shall be equal to the aperture at the bottom.

Let the cylindrical vessel of glass A B, Plate IV. fig. 1. have a hole in the bottom at C, furnished with a cylindrical ferule of copper of an inch diameter D, which is to be stopped with a piston G, well fitted to the ferule, and oiled, that it may yield to a moderate pressure. Let the piston be supported by a small rod G H, fastened at H to the silk which unites with the portion of the pulley M, with which the extremity of the lever M N is furnished, and which has for its centre of motion the point L. The other portion of the pulley N, which terminates the other extremity of the lever, is also furnished with lines of silk, which support the small bason or scale I. Upon the copper ferule D, fit a cylindrical tube of glass FE, the interior diameter of which is equal to that of the ferule, and its height equal to that of the vessel AB. When the apparatus is disposed in this manner, fill the tube EF with water, and continue to put small weights into the scale I, until the piston begins to rise. Afterwards take away the glass tube EF, and place the piston G in the copper ferule D, and pour water into the large vessel AB, and it will appear that the same weights as before in the bason I, will raise up the piston when the large vessel AB is entirely full. Hence it follows that there is the same power to be counteracted, whether there rests upon the piston only a column of water of its own size, or whether *the vessel AB is entirely full. Such a column, therefore, presses upon its base, independently of the rest of the water contained in the vessel.*

2. *Fluids press equally in all directions. In other* words, they not only press from the top to the bottom, like other bodies, but they also press according to their weight, upon all bodies that oppose them in a lateral direction, and even from the bottom to the top. Hence, if a cask is filled with liquid oil, the oil will run out if an aperture is made in the side, but when it is congealed it will not run out, on account of its having become a solid body; for solid bodies press only from their vertex to their base, and not laterally.

To understand this lateral pressure of fluids, and also that which they exert from their base towards their vertex, it is necessary to consider them as a mass of small globules deposited in a vessel; and to remember that these minute globules are not arranged regularly as upon a cord, but that very frequently one column exercises its pressure between two others, and has a propensity to displace them. It is by the same mode of reasoning that the pressure of fluids, from their base towards their vertex, is accounted for.

3. All the parts of the same fluid are in equilibrium with each other, whether they are contained in one vessel or many, provided they communicate with each other; and their surfaces also are always in a plane parallel to the horizon.

Thus in the vessel ABC, fig. 2, the bottom BC does not sustain a pressure equal to the whole quantity of fluid in the vessel, but only of a column whose base is CB, and height CE. Also in the vessel FGH, the bottom GH, fig. 3, sustains a pressure equal to what it would be if the vessel were as wide at the top as it is at the bottom.

This leads us to notice what is called the hydrostatical paradox, which is thus expressed, "That a quantity of fluid, however small, may be made to counterpoise a quantity however large." Thus, if to the wide vessel AB, fig. 4, the tube CD is attached, communicating with AB, and then water be poured into either of them, it will stand at the same height in both, consequently there is an equilibrium between them. It may thus be illustrated: Let ABDG, fig. 7, represent any cylindrical vessel, to the inside of which is fitted a cover C, which will slide up and down without suffering any water to pass between the edges. In the cover is inserted a small tube, CF, which is open at top, and communicates with the inside of the cylinder beneath the cover at C. The cylinder is filled with water, and the cover put on. Then if the cover is loaded with a weight, as a pound, it will be depressed, and the water rise in the tube to E, and the weight will be sustained. If another weight be added, the water will rise to F, and the weight sustained, and so on, according to the weight added, and the length of the tube. Now the weight of the water in the tube is but a few grains, yet its lateral pressure serves to sustain as much as the weight of a column of water whose base is equal to that in the tube. Thus the column E d produces a pressure in the water contained in the cylinder, equal to what would have been produced by the column A a D d; and as this pressure is exerted equally every way, the cover will be pressed upwards with a force equal to the weight of A a d D; consequently if A a d D weigh a pound, EC will sustain a pound: and the like of any other heights and weights.

The instrument commonly employed to show that a small quantity of water is capable of exerting great pressure is called the hydrostatic bellows. The use of this machine is now nearly laid aside; and an excellent substitute for it is found in the simple invention of the ingenious Ferguson, of which the following is his own description.

In fig. 4, ABCD is an oblong square box, in one end of which is a round groove, as at *a*, from top to bottom, for receiving the upright glass tube I, which is bent to a right angle at the lower end, as at *i* in fig. 5, and to that part is tied the neck of a large bladder K, which lies in the bottom of the box. Over this bladder is laid the moveable board L, fig. 6, in which is fixed an upright wire M; and leaden weights NN, to the amount of sixteen pounds, with holes in their middle, which are put upon the wire, over the board, and press upon it with all their force.

The cross bar *p* is then put on, to secure the tube from falling, and keep it in an upright position; and then the piece EFG is to be put on, the part G sliding tight into the dove-tailed groove H, to keep the weights NN horizontal, and the wire M upright; there being a round hole *e* in the part EF for receiving the wire. There are four upright pins in the four corners of the box within, each almost an inch long, for the board L to rest upon; to keep it from pressing the sides of the bladder below it close together at first.

The whole machine being thus put together, pour water into the tube at top; and the water will run down the tube into the bladder below the board; and after the bladder has been filled up to the board, continue pouring water into the tube, and the upper pressure which it will excite in the bladder will raise the board with all the weight upon it, even though the bore of the tube should be so small that less than an ounce of water would fill it.

Although this principle of the upward pressure of water was known to the ancients, it was never applied to any useful purpose till the late Mr. Joseph Bramah constructed on it the well-known *hydraulic press,* which is now so extensively used where great pressure is required.

This machine not only acts as a press, but is capable of many other useful applications, such as a jack for raising heavy loads, or even buildings;—to the purpose of drawing up trees by their roots, or the piles used in building.

Upon the principle of the upward pressure of fluids, a piece of lead may be made to swim in water, by immersing it to a proper depth, and keeping the water from getting above it. Let CD, fig. 8, plate V. be a glass tube open throughout, and G a flat piece of lead half an inch thick, fitted exactly to the lower end of the tube, but not to go within it. By means of the packthread L, the lead is held close to the bottom of the tube, and in this situation it is immersed in the water of the vessel K to somewhat more than eleven times its own thickness, because lead is more than eleven times heavier than water; then the thread L may be let go, but the lead will not fall, but be sustained by the upward pressure of the water below it. If some water be poured upon the lead, or if the tube be raised a little, the lead will fall by its own weight, which will then be too heavy for the pressure of the water round the tube upon the column of water below it.

II. The effects of gravity on fluids of different densities will, from what has preceded, not be very difficult to comprehend.

If two fluids of different densities are placed in a state of equipoise with each other, and have the same base, their perpendicular heights above the horizon will be in a reciprocal ratio to their densities or specific gravities.

If, for example, mercury is put into an inverted syphon, and water is poured into one of the branches, in order to elevate the mercury in the other branch one inch above its level, it is necessary that the water should be about thirteen inches and a half high. The height of the water then will be thirteen times and a half that of the mercury; because the specific gravity of mercury is about thirteen times and a half as great as that of water.

III. The action of fluids on solid bodies immersed in them forms the doctrine of specific gravity.

When a solid body is plunged into a fluid, it occupies a space in that fluid exactly equal to its own magnitude. The quantity of fluid then so displaced, either equals in density, and consequently in weight, the solid which displaced it; or, on the contrary, one of the two must weigh more than the other. In the last case, which is most common, the quantity by which the heavier body surpasses the lighter is called the specific weight or gravity.

If a body is heavier than the fluid in which it is immersed, it is evident that it will sink to the bottom by its specific gravity. If a body is lighter than the same bulk of the fluid into which it is plunged, a part of it will swim, and the remaining part which is immersed displaces a quantity of fluid, which weighs exactly as much as the whole of the solid body.

The instrument used for finding the specific gravities of bodies is called the hydrostatic balance, fig. 9.

It differs very little from a common balance that is nicely made; only it has a hook at the bottom of one of the scales, on which different substances that are to be examined may be hung by horse-hairs, so as to be immersed in a vessel of water, without wetting the scale.

If a body thus suspended under the scale, at one end of the balance, be first counterpoised in air by weights in the opposite scale, and then immersed in water, the equilibrium will be immediately destroyed; then, if as much weight be put into the scale from which the body hangs as will restore the equilibrium, without altering the weights in the opposite scale, that weight which restores the equilibrium will be equal to the weight of a quantity of water as large as the immersed body; and if the weight of the body in air be divided by what it loses in water, the quotient will show how much that body is heavier than its bulk of water. Thus, if a guinea suspended in air be counterbalanced by 129 grains in the opposite scale of the balance, and then, on its being immersed in water, it becomes so much lighter as to require 7¼ grains put into the scale over it, to restore the equilibrium, it shows that a quantity of water of equal bulk with the guinea weighs 7¼ grains, or 7·25; by which divide 129 (the weight of the guinea in air), and the quotient will be 17·793; which shows that the guinea is 17 793 times as heavy as its bulk of water. And thus any piece of gold may be tried, by weighing it first in air, and then in water; and if upon dividing the weight in air by the loss in water, the quotient comes out to be 17·793, the gold is good: if the quotient be 18, or between 18 and 19, the gold is very fine; but if it be less than 17, the gold is too much alloyed with other metal. By this method the specific gravities of all bodies that will sink in water may be found.

CHAPTER VI.

HYDRAULICS.

This branch of science is sometimes treated as forming a part of the preceding, but there are between the two several points in which they essentially differ; on which account we shall allot to Hydraulics a distinct chapter.

Hydraulics teach what relates to the motion of fluids, and how to determine their velocity and force. On the principles of this science all machines worked by water are constructed, as steam-engines, water-mills, common and forcing pumps, syphons, fountains, and fire-extinguishing engines.

GENERAL PRINCIPLES.

When water flows from a vessel which has a hole or aperture in the bottom, small in comparison to the width of the vessel, the water descends vertically, and the surface appears smooth, but at three or four inches from the bottom the particles turn from this direction, and proceed on all sides with a motion more or less oblique towards the aperture. The same effect takes place when water flows through an aperture laterally. The tendency of the particles towards the aperture is a necessary consequence of their perfect mobility; for they will certainly be directed towards the point where there is the least resistance, and that point is the aperture.

It is also to be observed, that in this case, at a small distance from the bottom, a kind of funnel is formed in the water, the point of which corresponds to the centre of the aperture; when, however, the water flows through a lateral orifice or aperture, there is formed only a kind of half funnel, which does not appear to commence till the surface is near touching the upper side of the hole. It is probable that the funnel begins to form itself from the first moment of the flow; but it does not become perceptible till the surface is only at a small distance from the bottom. It appears also, that the funnel commences higher or lower, according to the width of the bottom; and that the formation of it is less prompt or less perceptible, according to the proportion of the aperture to the extent of the bottom. The funnel is also augmented by any roughness which may exist at the sides or bottom of the vessel.

Water flows out of a small hole in the bottom of a vessel with a velocity equal to that which a ponderous body acquires in falling from a height equal to the vertical height of the surface of the fluid above the aperture.

The same law takes place in a lateral orifice; for the pressure of the fluid is equal (at the same depth) in all directions, and consequently produces the same degree of velocity.

A fluid in running out of an aperture acquires a velocity sufficient to make it remount to a vertical height equal to that of the fluid above the aperture, in the same manner as a falling body acquires a velocity capable of making it ascend to the height from which it descended.

It is evident, from the theory of falling bodies, that if the velocity of the fluid in running through the aperture was uniformly continued, the fluid would move through a space double the height of the fluid above the aperture, in the same time that a falling body would employ in descending from that height.

The height being the same, the velocity of the fluid in running out of the orifice will always be the same, whatever the species of the fluid may be, and whatever its density. It is true, that when the fluid has more density it presses more forcibly, but then the mass is more considerable; and it is evident, that when the moving powers are proportioned to the masses which they put in motion, the velocities are equal.

The quantities of a fluid discharged in the same space of time through different orifices, supposing the vessels equally full during the whole of the experiment, are to each other as the products of the areas of the apertures by the square roots of the heights.

It is found by experiment, that a circular orifice of an inch diameter, made in a thin vessel or partition, and under a surface of fluid four feet in height, will furnish, in one minute of time, 5436 cubic inches French.

If, therefore, it were an object to ascertain how much a circular orifice of two inches diameter, under nine feet of height from the surface of the water, would furnish in the same, the following proportion must be employed (it must be observed, that the orifice of two inches is four times as great as an orifice of one inch, because the areas of circles are as the squares of their diameters):

$$1 \times \sqrt{4} : 4 \times \sqrt{9} :: 5436 : x$$

Or at length,

$$2 : 12 :: 5436 : 32616$$

$$12$$

$$2)658232$$

The reader ought here to be reminded, that in every branch of hydraulics the deductions of theory are extremely uncertain, and, indeed, of but little use in any of the important purposes to which this science is applicable: the general laws deduced from experiment can alone be safely employed.

The motion of fluids, and the friction, and other causes by which they are impeded, form together one of the most elaborate and abstruse branches of mathematical philosophy, and would, we fear, prove very uninteresting to the generality of our readers.

The following rule, as stated by Professor Millington, will be found sufficiently correct for most practical purposes, and its extreme simplicity not a little enhances its value:

It may be practically assumed that water may flow through straight pipes of from 2 to 7 inches diameter, when lying horizontally, at the rate of 3 feet in a second, without much loss of power from friction, unless the length of the pipes be very considerable; and consequently to calculate the quantity of water that a pipe will deliver in a given time, it is only necessary to calculate the solid contents of a yard of any pipe in cubic inches, or any other measure of capacity, and to multiply this by the number of seconds contained in the given time, in order to obtain the delivery. Now, if the diameter in inches of any pipe be squared, and the right-hand figure of its square number be cut off by a decimal point, such square number will be the contents of a yard of such pipe in ale gallons and tenths. Thus, if a pipe is 6 inches in diameter, its square will be 36, which being divided as above makes 3·6, and shows that one yard of such pipe contains 3 gallons and 6 tenths. If the pipe were but two inches diameter, then its square 4 consists but of one figure, and must be considered as a decimal, thus ·4 indicates that the contents of a yard of such pipe contains 0·4—four-tenths of 1 gallon.

The nature of the motion, lateral pressure, gravity, and momentum of fluids being investigated by the mathematical principles of hydraulics and hydrostatics, the construction of mechanical engines for raising or moving water, and for procuring disposable power from its agency, follow as natural consequences.

In the formation of these, Mr. Millington observes, it must be kept in mind that water has a constant tendency to descend, which affords the principal resistance to be overcome in the one case, and the source of power in the other; and as water can never rise above its ordinary level, except by some extraneous force, so likewise in descending it can never produce a power equal to the elevation of more than its own quantity to a height equal to that from whence it flowed, since that would be contrary to the laws of hydrostatic equilibrium.

We shall now proceed to describe a few of the most useful and simple hydraulic machines.

Of the Syphon.

A syphon is a bent tube, ABC, fig. 10, made of glass, metal, &c. One branch of which, AB, is shorter than the other, BC. In order to make use of this instrument, place the extremity of the short branch in the vessel A, which may be supposed to contain any fluid matter, as water for instance. If the air then is drawn out of the syphon (fig. 11), by means of the long branch x, the liquor will begin to flow, and will not cease while the short branch AB remains immersed in the fluid. It is easy to see that the pressure of the air upon the surface of the fluid in the vessel is the cause of its discharge through the syphon. For suppose GF the confines of the atmosphere, all the points of the surface A of the liquor will be equally pressed by the column of air AF; if, therefore, at some point of this surface the pressure is suspended, the liquor must flow at that point, because it finds less resistance there than in any other part; this is therefore the obvious reason why the syphon becomes full immediately after the air is drawn out at the extremity C.

If the two branches of the syphon were of equal lengths, as BA, BD, the flow through the bent tube would not take place; because the column of air DG which would resist in D, being of an equal height with that which presses at A, would also be in equilibrium with it, in the same manner as the two columns of the fluid BA, BD. But since BC, one of the legs, is longer than the other, though the column of the air GC, which answers to it, is really longer than that which presses in A, yet it is not capable of preventing the passage of the fluid. To understand this more perfectly, let us consider the column of air GC to be divided into two parts, one of which, GD, would form an equipoise with the column of air FA, and would be capable of stopping the flow from the tube, if the branch BC ended in D. The portion of fluid which fills the part DC of the syphon will find no other resistance in C than one column of air DC of the same length with it, which is evidently very inferior to it in weight. This portion of fluid then flows out, because it greatly exceeds in weight the column of air which is opposed to it. But while it continues to flow, nothing sustains that which is above it, which flows necessarily, while the pressure of the air at A furnishes a new supply of fluid to replace that which runs out. It is by these means that the water in the syphon continues to flow without intermission; because the resistance of the air in C is as much exceeded as the length of the branch BC of the syphon exceeds that of the branch AB. In order to prove this, suppose there is added at C a tube to lengthen that branch, then it will plainly appear that in a given time more water will flow than would have been discharged without that augmentation to the branch BC.

Since it is the pressure of the air which elevates the fluid in the short branch BA, it follows, that the height of this branch is limited to thirty-two feet when the fluid is water, because the pressure of the atmosphere cannot elevate water higher; but when the liquor is mercury, the height of the short branch should not exceed thirty inches, because the atmosphere cannot sustain mercury at a greater height.

A syphon may be disguised in a cup, (fig. 12,) from which no liquor will flow until it be raised above the bend of the syphon; but when the efflux once begins, it will continue to flow till the vessel be emptied. This has been called Tantalus's cup, because it is usual to place a hollow figure over the inner tube of such a length, that when the fluid has got nearly up to the lips of the figure the syphon may begin to act, and empty the cup.

Intermitting springs, which puzzled philosophers formerly, are found to be natural syphons, which may be thus explained: Let A (fig. 13) be part of a hill, within which there is a cavity BB, and from this cavity a vein or channel running in the direction BCD. The rain that falls upon the side of the hill will sink and strain through the small pores and crevices in the hill, and fill the cavity BB with water. When the water rises to the level of C, the vein BCD will be full, and the water will run through it as a syphon, and will empty the cavity BB. It must then stop, and when the cavity is again filled, it will begin to run again.

The principal use to which the syphon is applied is that of drawing off liquors from one vessel to another, as represented in fig. 14.

Of the Pump.

There are two sorts of pumps, which essentially differ; and all the varieties are but modifications of these. One has a piston with a perforation and valve; the other has a solid piston: to the former is given the name of the common sucking-pump; the latter is denominated the forcing-pump.

Fig. 15 represents the common sucking-pump. AA is a cylinder of cast iron, bored smooth withinside; it has a flanch at the top, by which it is screwed to the wooden cistern B, which conveys the water away from the pump. It has also a flanch D at its lower end, to screw on the pipe E, which brings the water to the pump. In the same flanch is a pair of valves, *aa*; and the bucket or piston F, which slides within the barrel, has another similar pair of valves in it. This bucket is screwed to an iron rod G, which is moved up and down by some machine. When the bucket F descends, its valves *aa* open as in the figure, and allow the water which fills the barrel to pass through them.

When the bucket arrives at the bottom of the barrel, it is drawn up again; and as the valves shut, and prevent the water from returning through the bucket, it lifts all the water contained in the barrel into the cistern B. At the same time the bucket, in rising, makes a vacuum beneath it: the pressure of the atmosphere upon the surface of the water in the well causes it to mount up through the pipe E, open the valves *bb*, and fill the barrel AA. When the bucket begins to descend, the column of water beneath it descends also, till it is stopped by the shutting of the valves *bb*; the valves *aa* then open, and allow the water to pass through as before.

Fig. 16 is a forcing-pump. In this the barrel AA is screwed upon a square box BB, which has a pair of valves *aa* at the top of the pipe C, bringing water from the well; and another similar pair at the other end of the pipe D, which is likewise screwed to the square box. The plunger E is solid: when it is drawn up it makes a vacuum in the barrel, and draws the water up through the valves *aa* from the well to fill the barrel. The plunger is then forced down, the valves *aa* shut, and as the water has no other way out of the box, it passes through *bb* up the pipe D. The plunger is then drawn up, the valves *bb* shut, and *aa* open to supply the barrel as before.

Fig 17 is a lift-pump. The barrel AA is screwed by its top to a shorter barrel H, from which the crooked pipe B proceeds. A cover *h* is screwed over the top of the barrel H, with a stuffing-box in the middle of it; which is a box containing hemp, or other light substances, through which the piston-rod E passes. The piston F has two valves *bb* in it, similar to fig. 1; and at the bottom of the barrel are two valves similar to *aa* (fig. 16.) When the piston descends, the lower valves prevent the water from going out of the barrel; and the valves *bb* open, to let the water pass through them. When the piston returns, the valves in it shut, and it raises the water through the pipe B, the stuffing-box preventing its getting out at the top of the barrel, by the side of the piston-rod, as in fig. 1; and at the same time, by making a vacuum beneath it, filling the barrel through the lower valves in the same manner as the sucking-pump. The piston then descends, the lower valves shut, and *bb* open as before. In all the figures, W represents a hole in the bottom of the pump, to get at the valves to repair them; and when the pump is at work, a cover is screwed over it, as shown in fig. 17. Pumps constructed as in the drawings are seldom less than one or two feet in the bore of the barrel.

That eminently useful engine termed the *fire-engine*, or more properly, the fire extinguishing engine, is nothing more than two forcing-pumps so combined, that their joint action produces a constant and powerful stream of water, which may be directed at pleasure towards the point at which it is wanted.

The most approved construction of the fire-engine is, we believe, that of the ingenious Mr. Rowntree. It consists of a double force-pump of a peculiar construction, similar in its action to the well known beer engine, by the same inventor.

The following is a description of a common engine for extinguishing houses and other buildings, when on fire. It is composed of two barrels, in each of which a solid piston is worked by means of a double lever, one piston descending and the other ascending at the same time. These barrels are fixed in a vessel of water, with which they communicate by valves opening into them; and they also communicate with a strong vessel, by means of pipes, terminated by valves opening into it. If either of the pistons be raised, the water rushes out of the receiver through the valve; and the piston, being now depressed, forces the water into the vessel connected with the pipe: by repeated strokes of the pistons, the water in that vessel condenses the air above it; the elasticity of which, by pressing upon the surface of the fluid, is sufficient to force it in a continued stream through a pipe of any length.

The *steam-engine* is now so widely used wherever great, or even moderate power is wanted in mechanical operations, that every person ought to be able to form some idea of its nature, and the principles on which it acts. The merit of this grand invention is generally ascribed to the Marquis of Worcester; but if the idea originated with him, the perfecting of it belongs to the immortal James Watt, a native of Greenock. The improvements that have been made in the construction of the steam-engine within the last twenty years are so numerous, that in our little work it would be preposterous to attempt to describe them. We shall therefore content ourselves with giving our readers a brief description, and a representation of a modern steam-engine, which may, of course, be constructed of any required power, and applied to any purpose.

In plate VI. A represents a wrought iron boiler, about three parts filled with water; the bottom is considerably, and the sides a little, concave, that it may receive more fully the force of the flame circulating round it. Boilers are usually of an oblong form, and are furnished with a part that takes off, in order that a person may get in to clean them when needful; they have also a valve, called the safety-valve, opening upwards, which is loaded so that the steam escapes when it is stronger than the engine requires, and, if retained, would hazard the bursting of the boiler. It is not uncommon to have two boilers, one of which is a reserve, that the engine may not be stopped when the other requires repair.

B, is an apparatus for regulating the fire, and giving action to a bell, which regulates the quantity of coals and time of firing.

C, the steam-pipe from the boiler A to the valve I.

D, the steam-cylinder, generally called only "the cylinder;" it is connected at the top and bottom with the valve I.

E, the piston, which, by its connecting-rod *e*, gives motion to the beam F, the other end of which, by another connecting-rod, gives motion to the heavy fly-wheel G, by means of a crank. Thus, after the engine has begun to work, its power is accumulated in the fly-wheel, and may be disposed of at the pleasure of the engineer.

H, an eccentric circle on the axle of the fly-wheel G; it gives motion by its levers to the valve I.

I, a coffer-slide valve, which requires no packing to make it steam-tight, as there is always a vacuum under it: it answers the purpose of the four valves used in double-power engines, and from the simplicity of its construction, when well made at first, is not liable to get out of order.

K, the steam-admission valve and lever, connected with a governor, which regulates the speed of the engine.

L, the cylinder of the discharging-pump, for extracting the water and uncondensed vapour from the condenser M.

N, a small cistern, filled with water. Into this cistern enters a pipe from the condenser M, the top of which pipe is covered by a valve, which is called the blow-valve, sometimes the snifting-valve. Through this valve the air contained in the cylinder D, and passages from it, is discharged, previously to the engine being set in motion.

O, the eduction-pipe, which conducts the steam *from the valve I to the condenser M.*

P, the pump which supplies with water the cistern SS, in which the condenser and discharging-pump stand.

QQ, iron columns, of which the engine has four, although only two are shown; they stand upon one entire plate seen edgeway, on which the principal parts of the engine are fixed; by this means the beam and its accompaniments are supported without being connected with any part of the building, except the recess below the floor on which they stand.

RR, the recess below the floor, for containing the cistern of the discharging-pump, condenser, &c. This arrangement enables those engines to be fixed up and tried at the manufactory before they are sent off, which renders the refixing easy and certain.

Before the engine is set to work, the cylinder D, the condenser M, and the passages between them, are filled with common air, which it is necessary to extract. To effect this, by opening the valves, a communication is made between the steam-pipe C, the space below the piston in the cylinder D, the eduction-pipe O, and the condenser M. The steam will not at first enter the cylinder D, or will only enter it a little way, because it is resisted by the air; but the air in the eduction-pipe O, and the condenser M, it forcibly drives before it, and this part of the air makes its exit through the valve and water in the cistern N. The steam-admission valve is now closed, and the steam already admitted is converted into water, partly by the coldness of the condenser M, but principally by a jet of cold water which enters it through a cock opening into it from the well SS, in which the condenser is immersed. When this steam is condensed, all the space it occupied would be a vacuum, did not the air in the cylinder D expand, and fill all the space that the original quantity of it filled; but by the repetition of the means for extracting a part of the air, the remainder is blown out, and the cylinder becomes filled with steam alone. Suppose, then, the cylinder beneath the piston to be filled with steam, and the further admission of steam to that part of it be cut off, while the communication between it and the condenser remains open, it is obvious that there will soon be a vacuum in the cylinder, because as fast as the steam reaches the condenser it is converted into water by the coldness of that vessel and the jet playing within it.

At this moment, therefore, the steam is admitted above the piston, which it immediately presses down. As soon as the piston reaches to the bottom of the cylinder, the steam is admitted to the under side of it; and as the communication from the upper side of the piston to the condenser is opened, while the further admission of steam to that side during the upper stroke is prevented, the steam which had pressed the piston down passes into the condenser, and is converted into water.

The motion of the piston E, by this alternate admission and extraction of the steam on each side of it, is thus necessarily continued, and the distance of its upward and downward range is called the length of its stroke. It communicates its reciprocating motion, by the connecting-rod *e*, to the great beam F, and thence, by another connecting-rod and a crank, to the fly-wheel G.

To explain the rapid accumulation of power with an increase of the size of the engine, it must be observed, that the force of the steam generally used is somewhat greater than the pressure of the atmosphere; but supposing it to be no greater, as the atmospheric pressure is fifteen pounds on each square inch, a piston sixteen inches in diameter, containing 201 square inches of surface, will alternately be raised and depressed by a force equivalent to a weight of 3015 pounds. Here no allowance is made for friction, but after the requisite deduction on this account, which may be reckoned at one-third, the disposable part of the engine, derived from each stroke, will still be very great.

The condenser M, and the discharging-pump L, communicate by means of a horizontal pipe containing a valve *y* opening towards the pump; the piston *f* of this pump also contains two valves, and the cistern T, at the top of the pump-cylinder, contains other two valves, which, like those of the piston *f*, open upwards. When the piston E of the cylinder is depressed, the piston *f* of the discharging-pump, it will be obvious to inspection, is depressed likewise, and its valves open, while the valve *y* closes; hence the water from the condensed steam, as well as the injection-water, and any permanently elastic vapour or gas, which may be present, having passed through the valve *y*, passes through the piston *f*: and when that piston is drawn up, its valves close, and prevent their return, as in ordinary pump-work. The water and gas that have thus got above the piston, as the latter rises, open the valves at the bottom of the cistern T, in which the water remains till it is full, but the gas passes into the atmosphere. As the water in the cistern T is in a very hot state, it is sometimes, for the purpose of economizing fuel, pumped up, and returned to the boiler, the pump-rod being attached to the great beam. The utility of the discharging-pump L will now be appreciated, and it must be perceived how much more materially it contributes to the perfection of the vacuum in the cylinder D, than if the water from the condenser merely ran off by a pipe.

The steam constantly rushing into the condenser M, has a perpetual tendency to heat that vessel, as well as the water of the cistern SS, in which it stands. The whole of the steam, if this were unchecked, would not be condensed, or the condensation would not be sufficiently rapid, because the injection-water itself flows out of this cistern. A part of the water is therefore allowed to flow from this cistern by a waste pipe, and an equal quantity of cold is constantly supplied by the pump P.

In Newcomen's engine, which, as it acted by the pressure of the atmosphere, is often called an atmospherical engine, the cylinder was open at the top, and therefore, during the descent of the piston, the air exerted a great power in cooling it; but in the modern engines, where steam is the active power both in raising and depressing the piston, the top of the cylinder is closed with an iron lid, and not an atom of steam can escape, except at the proper time, into the condenser. In order that the connecting-rod *e* may work freely, and yet possess this desirable property of being steam-tight, it passes through what is called a *stuffing* or *packing-box*. This stuffing consists of some material which the steam will rather adapt to its office than injure; leather, which is used for the stuffing or collars of machines never to be subjected to heat, will not answer here: hempen yarn is the material usually employed. The rod of the piston *f* passes through a stuffing-box of the same kind as that of the piston E; and the pistons themselves are surrounded with stuffing.

The cylinder D is surrounded by a case, to keep it from being cooled by contact with the external air. The extremity, or any given point removed from the centre of the great beam, can describe only the arc of a circle; but it is necessary that the piston-rod *e* should rise and fall vertically. Newcomen effected this object by fixing the end of the beam into the arc of a circle, the radius of which was equal to the distance from the centre of the beam: a chain went over this arc, and was fastened on the higher end of it: this simple contrivance effectually answered his purpose, because in his engine the effective stroke was only downwards; but here, in a double-power engine, where the stroke is both upwards and downwards, a chain would yield in rising, and be altogether unsuitable. An apparatus is therefore used, called the parallel joint, which is easily understood by inspection. By this means the rod *e* not only rises and falls perpendicularly, but is perfectly rigid, and communicates all its motion to the great beam in each direction of its motion. The connecting-rod *g* does not require the same contrivance, because it does not rise and fall perpendicularly; its lower end, with the outer end of the crank, describing a circle: it has therefore only a simple joint, admitting of this deviation.

CHAPTER VII.

PNEUMATICS.

THE term Pneumatics, from *πνευμα, a spirit*, denotes that particular branch of science which treats of the mechanical properties of air.

The air is a fluid in which we live, and which we breathe; it entirely envelopes our globe, and extends to a considerable distance in all directions. This air, together with the various gases, steams, vapours, and exhalations that are constantly rising into it, and which form clouds, we denominate by the general term atmosphere.

Atmospheric air is consequently of a very mixed nature; but in its purest state it is found by chemical examination to consist of two permanently elastic gases or airs, called nitrogen and oxygen, in the proportion of about 79 parts of the former to 21 of the latter by measure, or 77 and 23 parts by weight, and as the one or the other of these gases prevails, the air is more or less wholesome. The chemical properties of the different airs or gases will be noticed when we come to treat of chemistry; at present we have to do with the mechanical properties of the atmospheric air only.

As air is possessed of gravity in common with all other fluids, it must press upon bodies in proportion to the depth at which they are immersed in it; and it also presses in every direction in common with all other fluids.

It differs from all other fluids in the four following particulars: 1. It can be compressed into a much less space than it naturally possesses: 2. It cannot be congealed or fixed as other fluids may: 3. It is of a different density in every part upward from the earth's surface; decreasing in its weight, bulk for bulk, the higher it rises: 4. It is of an elastic or springy nature and the force of its spring is equal to its weight.

When the air is at rest, we can move in it with the utmost facility; nor does it offer to us a sensible resistance, except the motion is quick, or the surface opposed to it considerable; but when that is the case, its resistance is very sensible, as may be easily perceived by the motion of a fan.

When air is in motion, it constitutes wind; which is nothing more than a current or stream of air, varying in its force, according to the velocity with which it flows.

The invisibility of air, therefore, is only the consequence of its transparency; but it is possessed of all the common properties of matter. When a vessel is empty, in the usual way of speaking, it is, in fact, still filled with air.

But it is possible to empty a vessel even of the air which it contains, by which means we shall be able to discover several properties of this fluid. The instrument, or machine, by which this operation is performed is called an air-pump. As it is by means of this useful instrument that all the mechanical properties of air are demonstrated, it will be necessary to describe its construction, and the manner of using it, before we proceed to the experiments that are made with it.

Plate XII. fig. 1, is the air-pump that is now most in use. AA are two brass barrels, each containing a piston, with a valve opening upwards. They are worked by means of the winch H, which has a pinion that fits into the teeth of the racks CC, which are made upon the ends of the pistons, and by this means moves them up and down alternately.

On the square wooden frame D E, there are placed a brass plate G, ground perfectly flat, and also a brass tube, let into the wood, communicating with the two barrels and the cock I, and opening into the centre of the brass plate at *a*. The glass vessel K, to be emptied or exhausted of air, has its rim ground quite flat, and rubbed with a little pomatum, or hog's lard, to make it fit more closely upon the brass plate of the pump. These vessels are called receivers.

Having shut the cock I, the pistons are worked by the winch; and the air being suffered to escape when the piston is forced down, because the valve opens upwards, but prevented from returning into the vessel for the same reason, the receiver is gradually exhausted, and will then be fixed fast upon the pump-plate. By opening the cock I, the air rushes again into the receiver.

Although we have here described the common table air-pump, it is an article of which we by no means approve; it may do very well for the exhibition of the common experiments, but where great nicety and quickness of exhaustion are required it often fails. Cuthbertson's double-barreled air-pump, which stands table height, is at once the most elegant and powerful instrument that can be desired for pneumatical purposes.

Of the Pressure of the Air.

When the surface of a fluid is exposed to the air, it is pressed by the weight of the atmosphere equally on every part, and consequently remains at rest. But if the pressure is removed from any particular part, the fluid must yield in that part, and be forced out of its situation.

Into the receiver A, fig. 2, put a small vessel with quicksilver *z*, or any other fluid, and through the collar of leathers at B suspend a glass tube *x*, closed, or hermetically sealed, as it is called, over the small vessel. Having exhausted the receiver, let down the tube into the quicksilver, which will not rise into the tube as long as the receiver continues empty. But re-admit the air, and the quicksilver will immediately ascend. The reason of this is, that upon exhausting the receiver, the tube is likewise emptied of air; and therefore, when it is immersed in the quicksilver, and the air re-admitted into the receiver, all the surface of the quicksilver is pressed upon by the air, except that portion which lies above the orifice of the tube; consequently, it must rise in the tube, and continue so to do until the weight of the elevated quicksilver presses as forcibly on that portion which lies beneath the tube, as the weight of the air does on every other equal portion without the tube.

A square column of quicksilver twenty-nine and a half inches high, and an inch thick, weighs just fifteen pounds, consequently, the air presses with a weight equal to fifteen pounds upon every square inch of the earth's surface; and 144 times as much, or 2160 pounds, upon every square foot.

The pressure of the air is beautifully illustrated by what are called the Magdeburgh hemispheres. These are represented by AB, fig. 3, and consist of two hollow hemispheres of brass, which are made to fit upon each other by a ground joint rendered air-tight by a little pomatum. Having screwed off the handle at C, put both the hemispheres together, and screw them into the pump-plate, and turn the cock E, so that the pipe may be open all the way into the cavity of the hemispheres; then exhaust the air out of them, and turn the cock; unscrew the hemispheres from the pump, and having put on the handle C, let two strong men try to pull the hemispheres asunder by the rings, which they will find it difficult to do; for if the diameter of the hemispheres be four inches, they will be pressed together by the external air with a force equal to 190 pounds.

Screw the end of the brass pipe B, fig. 4, into the pump-plate, and turn the cock until the pipe is open; cover the plate *a* with the tall receiver G H, which is close at top; then exhaust the air out of the receiver, and turn the cock *e* to keep it out; which done, unscrew the pipe from the pump, and set the end of it into a basin of water, and turn the cock to open the pipe; and as there is no air in the receiver, the pressure of the atmosphere on the water in the basin will drive the water forcibly through the pipe, and make it play up in a jet to the top of the receiver.

Of the Elasticity of the Air.

To show the elasticity or spring of the air, tie up a very small quantity of air in a bladder, and put it under the receiver; then exhaust the air out of the receiver, and the air which is confined in the bladder (having nothing to act against it) will expand by the force of its spring, so as to fill the bladder completely. But upon letting the air into the receiver again, it will overpower that in the bladder, and press its sides close together.

If the bladder so tied up is put into a wooden box, and has twenty or thirty pounds weight of lead placed upon it, and the box is covered with a close receiver, upon exhausting the air out of the receiver, that which is confined in the bladder will expand itself so as to raise up all the lead by the force of its spring.

A very pleasing variety of this experiment is exhibited by lecturers with what is called the condensed air-fountain. Take a strong copper vessel, fig. 5, having a tube that screws into the neck of it so as to be air tight, and long enough to reach nearly to the bottom. Having poured a quantity of water into the vessel, so as to fill it about three parts full, and screwed in the tube, adapt to it a condensing syringe, and condense the air in the vessel; shut the stop-cock, and unscrew the syringe; then, on opening the stop-cock, the air acting upon the water in the vessel will force it out into a jet of very great height. A number of different kinds of jets may be screwed on the tube, such as stars, wheels, &c. forming a very pleasing appearance.

But the most striking pneumatic experiment for showing the elasticity of compressed air is the air-gun. By means of this instrument bullets may be propelled with a force nearly equal to that of gun-powder.

Fig. 6 represents the condenser for forcing the air into the ball. At the end *a* of this instrument is a male screw, on which the hollow ball *b* is screwed, in order to be filled with condensed air. In the inside of this ball is a valve, to hinder the air after it is injected from making its escape until it is forced open by a pin, against which the hammer of the lock strikes, which then lets out as much air as will drive a ball with considerable force to a great distance.

When you condense the air in the ball, place your feet on the iron cross *h h*, to which the piston-rod *d* is fixed; then lift up the barrel *e a*, by the handles *i i*, until the end of the piston is brought between *e* and *c*: the barrel *a c* will then be filled with air through the hole *e*. Then thrust down the barrel *a c* by the handles *i i*, until the piston *e* joins with the neck of the iron ball at *a*: the air, being thus condensed between *e* and *a*, will force open the valve in the ball; and when the handles *i i* are lifted up again, the valve will close, and keep in the air; so by rapidly continuing the stroke up and down, the ball will presently be filled; after which, unscrew the ball of the condenser, and screw it upon another male screw, which is connected with the barrel, and goes through the stock of the gun, as represented fig. 7. Twelve dwts. of air have been injected into a ball of 3·75 inches diameter, which has discharged 15 bullets with considerable force.

It may be expected that we should here give some account of the old magazine air-gun, but we deem that altogether unnecessary, as the modern make of the instrument is far superior, and universally adopted. And, indeed, all the advantages of that clumsy article are combined with the lightest form in which the air-gun is at present made.

In many pneumatic experiments it is required to effect strong condensations of air, and sometimes of gases. For this purpose, an instrument called a condenser, represented at fig. 1, plate VIII. is used. It consists of a brass barrel containing a piston, which has a valve opening downwards; so that as the piston is raised the air passes through the valve; but as the piston is pushed down, the air cannot return, and is therefore forced through a valve at the bottom of the barrel, that allows it to pass through into the receiver B, but prevents it from returning. Thus, at every stroke of the piston, more air is thrown into the receiver, which is of very thick and strong glass. The receiver is held down upon the plate C by the cross piece D, and the screws E F. The air is let out of the receiver by the cock G, which communicates with it.

There are numerous experiments besides the above to illustrate the mechanical properties of air, but these are sufficient for our purpose; and the reader will find some instruments described when we come to the science of meteorology, which are generally considered as belonging exclusively to pneumatics.

CHAPTER VIII.

ACOUSTICS.

Acoustics, in physics, is that science which instructs us in the nature of sound. It is divided by some writers into diacoustics, which explains the properties of those sounds that come distinctly from the sonorous body to the ear; and catacoustics, which treats of reflected sounds: but this distinction is not necessary.

Hearing is produced by the air which intervenes between the thing sounding and the ear. The air is agitated in a spherical form, and moves off in waves, and falls on the ear, in the same manner as water undulates in circles when a stone has been thrown into it.

The invention of the air-pump gave the first opportunity of deciding by experiment whether the elastic undulations of air were the causes of sound; and the trial fully established the point; for a bell rung in vacuo gave no sound, and one rung in condensed air gave a very loud one. It was therefore received as a doctrine in general physics, that air was the vehicle of sound. The celebrated Galileo, the parent of mathematical philosophy, discovered the nature of that connexion between the lengths of musical chords and the notes which they produced, which had been observed by Pythagoras, or learned by him in his travels in the East, and which he made the foundation of a refined and beautiful science, the theory of music. Galileo showed, that the real connexion subsisted between the tones and the vibrations of these chords, and that their different degrees of acuteness corresponded to the different frequency of their vibrations.

Dr. Derham has proved by experiment, that all sounds whatever travel at the same rate. The sound of a gun, and the striking of a hammer, are equally swift in their motions; the softest whisper flies as swiftly, as far as it goes, as the loudest thunder. To these we may add, that smooth and clear sounds proceed from bodies that are homogeneous, and of an uniform figure; and harsh or obtuse sounds from such as are of a mixed matter and irregular figure. The velocity of sounds is to that of a brisk wind as fifty to one. The strength of sounds is greatest in cold and dense air, and least in that which is warm and rarefied. Every point against which the pulses of sound strike becomes a centre from which a new series of pulses are propagated in every direction. Sound describes equal spaces in equal times.

There is probably no substance which is not in some measure a conductor of sound; but sound is much enfeebled by passing from one medium to another.

If a person tie a poker or any other piece of metal on to the middle of a strip of flannel about a yard long, then press with his thumbs or fingers the ends of the flannel into his ears, while he swings the poker against any obstacle, as an iron or steel fender, he will hear a sound very like that of a large church bell.

Sound, like light, after it has been reflected from several places, may be collected in one point, as into a focus; and it will be there more audible than in any other part, even than at the place from whence it proceeded. On this principle it is that a whispering gallery is constructed. The form of a whispering gallery must be that of a concave hemisphere, as ABC, plate VIII. fig. 2; and if a low sound or whisper be uttered at A, the vibrations expanding themselves every way will impinge on the points D, D, D, &c. and from thence be reflected to E, E, E, and from thence to the points F and G, till at last they all meet in C, where the sound will be the most distinctly heard. The augmentation of sound by means of speaking-trumpets is usually illustrated in the following manner: Let

ABC, fig. 3, be the tube, BD the axis, and B the mouth-piece for conveying the voice to the tube; then it is evident when a person speaks at B in the trumpet, the whole force of his voice is spent upon the air contained in the tube, which will be agitated through its whole length, and, by various reflections from the side of the tube to the axis, the air along the middle part of the tube will be greatly condensed, and its momentum proportionably increased, so that when it comes to agitate the air at the orifice of the tube AC, its force will be as much greater than what it would have been without the tube, as the surface of a sphere, whose radius is equal to the length of the tube, is greater than the surface of the segment of such a sphere whose base is the orifice of the tube.

An echo is a reflection of sound striking against some object, as an image is reflected in a glass: but it has been disputed what are the proper qualities in a body for thus reflecting sounds. It is in general known that caverns, grottoes, mountains, and ruined buildings, return this reflection of sound. We have heard of a very extraordinary echo, at a ruined fortress near Louvain, in Flanders. If a person sung, he only heard his own voice, without any repetition; on the contrary, those who stood at some distance heard the echo, but not the voice; but then they heard it with surprising variations, sometimes louder, sometimes softer, now more near, then more distant. There is an account in the Memoirs of the French Academy of a similar echo near Rouen. It has been already observed, that every point against which the pulses of sound strike becomes the centre of a new series of pulses, and sound describes equal distances in equal times; therefore, when any sound is propagated from a centre, and its pulses strike against a variety of obstacles, if the sum of the right lines drawn from that point to each of the obstacles, and from each obstacle to a second point, be equal, then will the latter be a point in which an echo will be heard. Thus let A, fig. 4, be the point from which the sound is propagated in all directions, and let the pulses strike against the obstacles C, D, E, F, G, H, I, &c. each of these points becomes a new centre of pulses by the first principles, and therefore from each of them one series of pulses will pass through the point B. Now if the several sums of the right lines $\overline{AC+CB}$, $\overline{AD+DB}$, $\overline{AE+EB}$, $\overline{AG+GB}$, $\overline{AH+HB}$, $\overline{AI+IB}$, &c., be all equal to each other, it is obvious that the pulses propagated from A to these points, and again, from these points to B, will all arrive at B at the same instant, according to the second principle; and therefore, if the hearer be in that point, his ear will at the same instant be struck by all these pulses.

The following simple experiment will serve to illustrate the principle of the echo.

If a bell, a, fig. 5, be struck, and the undulations of the air strike the wall cd in a perpendicular direction, they will be reflected back in the same line; and if a person be situated between a and c, as at x, he would hear the sound of the bell by means of the undulations as they went to the wall, and he would hear it again as they came back, after the reflection, which would be the echo of the sound. So a person standing at x might, in speaking in the direction of the wall cd, hear the echo of his own voice. But in both cases the distance cx must be 63 or 64 feet. If the undulations strike against the wall obliquely, they will be reflected off obliquely on the other side; if, for instance, a person stand at m, and there be any obstacle between that place and the bell, so as to prevent him hearing the direct sound, he may nevertheless hear the echo from the wall cd, provided the direct sound fall in that sort of oblique direction so as to force the reflected undulations along the line cm.

Fig. 6 is a representation of the Eolian harp, which was probably invented by Kircher. This instrument may be made by almost any carpenter; it consists of a long narrow box of very thin deal, about five or six inches broad, and two inches deep, with a circle in the middle of the upper side of an inch and a half in diameter, in which is drilled small holes. On this side seven, ten, or more strings of very fine gut are stretched over bridges at each end, like the bridge of a fiddle, and screwed up or relaxed with screw-pins. The strings are all tuned to one and the same note; and the instrument is placed in some current of air, where the wind can pass over its strings with freedom. A window, of which the width is exactly equal to the length of the harp, with the sash just raised to give the air admission, is a proper situation. When the air blows upon these strings with different degrees of force, it will excite different tones of sound; sometimes the blast brings out all the tones in full concert, and sometimes it sinks them to the softest murmurs.

There are various deceptions, founded on the principles of acoustics, frequently exhibited in public, among the most complete of which may be mentioned the Invisible Girl, which has been admired in every part of the country as an ingenious contrivance.

CHAPTER IX.

OPTICS.

This science is so named from the Greek term ὀπτομαι, *I see*, and is used to denote that branch of natural philosophy which treats of the nature and properties of light, and of the changes which it undergoes either in its direction when transmitted through bodies, either natural or artificial,—when reflected from their surfaces, or when passing by them at a small distance.

Definitions.

1. Light is a substance, the particles of which are extremely small, and these, by striking on our visual organs, give us the sensation of seeing.

2. The particles of light are emitted from what are called luminous bodies, such as the sun, a fire, a torch, or candle, &c. &c. It is reflected or sent back by what are termed opaque bodies, or those which have no power of affording light in themselves.

3. Light, whether emitted or reflected, always moves in straight or direct lines, as may easily be proved by looking into a bent tube, which evidently obstructs the progress of the light in direct lines.

4. By a ray of light, is usually meant the least particle of light that can be either intercepted or separated from the rest. A beam of light is generally used to express something of an aggregate or mass of light greater than a single ray.

5. Parallel rays are such as proceed equally distant from each other through their whole course. The distance of the sun from the earth is so immense, that rays proceeding from the body of that luminary are generally regarded as parallel.

6. Converging rays are such as, proceeding from any body, approach nearer and nearer to each other, and tend to unite in a point. The form of rays thus tending to an union in a single point has been compared to that of a candle-extinguisher; it is in fact a perfect cone.

7. Diverging rays are those which, proceeding from a point, continue to recede from each other, and exhibit the form of an inverted cone.

8. A small object, or a small single point of an object, from which rays of light diverge, or indeed proceed in any direction, is sometimes called the radiant, or radiant point.

9. Any parcel of rays, diverging from a point, considered as separate from the rest, is called a pencil of rays.

10. The focus of rays is that point to which converging rays tend, and in which they unite and intersect, or cross each other. It may be considered as the apex or point of the cone; and it is called the focus (or fire-place), because it is the point at which burning-glasses burn most intensely.

11. The virtual or imaginary focus is that supposed point behind a mirror or looking-glass, where the rays would have naturally united, had they not been intercepted by the mirror.

12. Plane mirrors or speculas are those reflecting bodies, the surfaces of which are perfectly plain or

even, such as our common looking-glasses. Convex and concave mirrors are those the surfaces of which are curved.

13. An incident ray is that which comes from any body to the reflecting surface; the reflecting ray is that which is sent back or reflected.

14. The angle of incidence is the angle which is formed by the line which the incident ray describes in its progress, and a line drawn perpendicularly to the reflecting surface; and the angle of reflection is the angle formed by the same perpendicular and reflected ray. The angle comprehended between the incident ray and the perpendicular, is the angle of incidence; and that between the refracted ray and the perpendicular, is the angle of refraction.

15. By a medium opticians mean any thing which is transparent, such as void space, air, water, or glass, through which consequently the rays of light can pass in straight lines.

16. The refraction of the rays of light is their being bent, or attracted out of their course, in passing obliquely from one medium to another of a different density, and which causes objects to appear broken or distorted, when part of them is seen in a different medium.

17. A lens is glass ground into such a form as to collect or disperse the rays of light which pass through it. These are of different shapes, and from thence receive different names. A plano-convex has one side flat, and the other convex, as A, plate IX. fig. 1. A plano-concave is flat on one side, and concave on the other, as B. A double convex, is convex on both sides, as C. A double concave, is concave on both sides, as D. A meniscus, is convex on one side and concave on the other, as E. A line passing through the centre of a lens, as F G, is called its axis.

18. Vision is performed by a contrivance of this kind. The crystalline humour, which is seated in the fore-part of the human eye, immediately behind the pupil, is a perfect convex lens.

19. The magnitude of the image painted on the retina will also depend on the greatness or obtuseness

of the angle under which the pencil of rays proceeding from the extreme points of the object enters the eye.

20. The prism used by opticians is a triangular piece of fine glass, which has the power of separating the rays of light.

Of Refraction.

If the rays of light, after passing through a medium, enter another of a different density perpendicular to its surface, they proceed through this medium in the same direction as before. Thus the ray O P, fig. 2, proceeds to K in the same direction. But if they enter obliquely to the surface of a medium, either denser or rarer than what they moved in before, they are made to change their direction in passing through that medium. If the medium which they enter be denser, they move through it in a direction nearer to the perpendicular drawn to its surface. Thus A C, upon entering the denser medium H G K, instead of proceeding in the same direction A L, is bent into the direction C F, which makes a less angle with the perpendicular O P. On the contrary, when light passes out of a denser into a rarer medium, it moves in a direction farther from the perpendicular. Thus, if S C were a ray of light which had passed through the dense medium H G K, on arriving at the rarer medium it would move in the direction C A, which makes a greater angle with the perpendicular. This refraction is greater or less, that is, the rays are more or less bent or turned aside from their course, as the second medium through which they pass is more or less dense than the first.

Upon a smooth board, about the centre C, describe a circle H O K P; draw two diameters of the circle, O P, H K, perpendicular to each other; draw A D M perpendicular to O P; cut off D T and C I equal to three-fourths D A; through T I, draw T I S, cutting the circumference in S; N S drawn from S perpendicularly upon O P, will be equal to D T, or three-fourths of D A. Then if pins be stuck perpendicularly at A, C, and S, and the board be dipped in the water as far as the line H K, the pin at S will appear in the same line with the pins at A and C. This shows, that the ray which comes from the pin S is so refracted at C, as to come to the eye along the line C A; whence the sine of incidence A D is to the sine of refraction N S, as 4 to 3. If other pins were fixed along C S, they would all appear in A C produced; which shows that the rays are bent at the surface only. The same may be shown, at different inclinations of the incident ray, by means of a moveable rod turning upon the centre C, which always keep the ratio of the sines A D, N S, as 4 to 3. Also the sun's shadow, coinciding with A C, may be shown to be refracted in the same manner. The image L, of a small object S, placed under water, is one-fourth nearer the surface than the object. And hence the bottom of a pond, river, &c. is one-third deeper than it appears to a spectator.

To prove the refraction of light in a different way, take an upwright empty vessel into a dark room; make a small hole in the window-shutter, so that a beam of light may fall upon the bottom at *a*, fig. 3, where you may make a mark. Then fill the bason with water, without moving it out of its place, and you will see that the ray, instead of falling upon *a*, will fall at *b*. If a piece of looking-glass be laid in the bottom of the vessel, the light will be reflected from it, and will be observed to suffer the same refraction as in coming in; only in a contrary direction. If the water be made a little muddy, by putting into it a few drops of milk, and if the room be filled with dust, the rays will be rendered much more visible.

In connexion with the subject of refraction, it may be proper just to notice the doctrine of the Polarization of light. This new branch of optical science sprang from the ingenuity of Malus. It has been since cultivated by MM. Arago, Fresnel, and Biot, in France, and by Dr. Brewster, in this country.

An excellent article on the subject has appeared in the Supplement to the Encyclopædia Britannica, by M. Arago.

If a solar ray fall on the anterior surface of an unsilvered mirror plate, making an angle with it of 35° 25′, the ray will be reflected in a right line, so that the angle of reflexion will be equal to the angle of incidence. In any point of its reflected path, receive it on another plane of similar glass, it will suffer in general a second partial reflexion. But this reflexion will vanish, or become null, if the second plate of glass form an angle of 35° 25′ with the first reflected ray, and at the same time be turned, so that the second reflexion is made in a plane perpendicular to that in which the first reflexion takes place. For the sake of illustration: suppose that the plane of incidence of the ray on the first glass coincides with the plane of the meridian, and that the reflected ray is vertical. Then, if we make the second inclined plate revolve, it will turn around the reflected ray, forming always with it the same angle; and the plane in which the second reflexion takes place will necessarily be directed towards the different points of the horizon, in different azimuths. This being arranged, the following phenomena will be observed.

When the second plane of reflexion is directed in the meridian, and consequently coincides with the first, the intensity of the light reflected by the second glass is at its maximum.

In proportion as the second plane, in its revolution, deviates from its parallelism with the first, the intensity of the reflected light will diminish.

Finally, when the second plane of reflexion is placed in the prime vertical, that is, east and west, and consequently perpendicular to the first, the intensity of the reflexion of light is absolutely null on the two surfaces of the second glass, and the ray is entirely transmitted.

Preserving the second plate at the same inclination to the horizon, if we continue to make it revolve beyond the quadrant now described, the phenomena will be reproduced in the inverse order; that is, the intensity of the light will increase, precisely as it diminished, and it will become equal, at equal distances from the east and west. Hence, when the second plane of reflexion returns once more to the meridian, a second maximum of intensity equal to the first recurs.

From these experiments it appears, that the ray reflected by the first glass is not reflected by the second, under this incidence, when it is presented to it by its east and west sides; but that it is reflected, at least in part, when it is presented to the glass by any two others of its opposite sides. Now, if we regard the ray as an infinitely rapid succession of a series of luminous particles, the faces of the ray are merely the successive faces of these particles. We must hence conclude, that these particles possess faces endowed with different physical properties, and that in the present circumstance, the first reflexion has turned towards the same sides of space similar faces, or faces equally endowed at least with the property under consideration. It is this arrangement of its molecules which Malus named the *polarization* of light, assimilating the effect of the first glass to that of a magnetic bar, which would turn a series of magnetic needles, all in the same direction.

Hitherto we have supposed that the ray, whether incident or reflected, formed with the two mirror plates an angle of 35° 25′; for it is only under this angle that the phenomenon is complete. Without changing the inclination of the ray to the first plate, if we vary ever so little the inclination of the second, the intensity of the reflected light is no longer null in any azimuth, but it becomes the feeblest possible in the prime vertical in which it was formerly null.

Similar phenomena may be produced, by substituting for the mirror glasses polished plates formed for the greater part of transparent bodies. The two planes of reflexion must always remain rectangular, but they must be presented to the luminous ray at different angles, according to their nature. Generally, all polished surfaces have the property of thus polarizing, more or less completely, the light which they reflect under certain incidences; but there is for each of them a particular incidence, in which the polarization it impresses is most complete; and for a great many, it amounts to the whole of the reflected light.

When a ray of light has received polarization in a certain direction, by the processes now described, it carries with it this property into space, preserving it without perceptible alteration, when we make it traverse perpendicularly a considerable mass of air, water, or any substance possessed of single refraction. But the substances which exercise double refraction, in general alter the polarization of the ray, and apparently in a sudden manner, and communicate to it a new polarization of the same nature, but in another direction. It is only in certain directions of the principal section, that the ray can escape this disturbing force.

On Reflexion.

When a ray of light falls upon any body, it is reflected, so that the angle of incidence is equal to the angle of reflexion; and this is the fundamental fact upon which all the properties of mirrors depend. Let a ray of light, passing through a small hole into a dark room, be reflected from a plane mirror, at equal distances from the point of reflexion, the incident, and the reflected ray, will be at the same height from the surface.

Again, if from a centre, C, with the radius, C A, the circle, AMP, be described, the arc, AO, will be found equal to the arc, OM, therefore the angle of incidence is equal to the angle of reflexion. The same is found to hold in all cases when the rays are reflected at a curved surface, whether it be convex or concave.

The rays which proceed from any remote terrestrial object, are nearly parallel at the mirror; not strictly so, but come diverging to it in separate pencils, or, as it were, bundles of rays, from each point of the side of the object next the mirror; therefore they will not be converged to a point at the distance of half the radius of the mirror's concavity from its reflecting surface, but in separate points at a little greater distance from the mirror. And the nearer the object is to the mirror, the further these points will be from it; and an inverted image of the object will be formed in them, which will seem to hang pendent in the air; and will be seen by an eye placed beyond it (with regard to the mirror), in all respects like the object, and as distinct as the object itself.

If a man place himself directly before a large concave mirror, but farther from it than its centre of concavity, he will see an inverted image of himself in the air, between him and the mirror, of a less size than himself. And if he hold out his hand towards the mirror, the hand of the image will come out towards his hand, and coincide with it, of an equal bulk, when his hand is in the centre of concavity; and he will imagine he may shake hands with his image. If he reach his hand further, the hand of the image will pass by his hand, and come between it and his body; and if he move his hand towards either side, the hand of the image will move towards the other; so that whatever way the object moves, the image will move the contrary way. A by-stander will see nothing of the image, because none of the reflected rays that form it enter his eyes.

The images formed by convex specula are in positions similar to those of their objects; and those also formed by concave specula, when the object is between the surface and the principal focus: in these cases the image is only imaginary, as the reflected rays never come to the foci from whence they seem to diverge. In all other cases of reflexion from concave specula, the images are in positions contrary to those of their objects, and these images are real, for the rays after reflexion do come to their respective foci.

Of Colours.

The origin of colours is owing to the composition which takes place in the rays of light, each heterogeneous ray consisting of innumerable rays of different colours; this is evident from the separation that ensues in the well-known experiment of the prism. A ray being let into a darkened room, fig. 4. through a small round aperture *z*, would pass on to *y*, where it would form a white round image; but if a glass prism be interposed, the ray will, by the refractive power of the prism, be considerably dilated, and will exhibit on the opposite wall an oblong image, *ab*, called a spectrum, variously coloured, the extremities of which are bounded by semicircles, and the sides are rectilinear. The colours are commonly divided into seven, which, however, have various shades, gradually intermixing at their juncture. Their order, beginning from the side of the refracting angle of the prism, is red, orange, yellow, green, blue, purple, violet.

The obvious conclusion from this experiment is, that the several component parts of solar light have different degrees of refrangibility, and that each subsequent ray in the order above mentioned is more refrangible than the preceding.

As a circular image would be depicted by the solar ray unrefracted by the prism, so each ray that suffers no dilatation by the prism, would mark out a circular image. Hence, it appears, that the spectrum is composed of innumerable circles of different colours. The mixture, therefore, is proportionable to the number of circles mixed together; but all such circles are mixed together, whose centres lie between those of two contingent circles, consequently the mixture is proportionable to the interval of those centres, *i. e.* to the breadth of the spectrum. If, therefore, the breadth can be diminished, retaining the length of the rectilinear sides, the mixture will be lessened proportionably, and this is done by the following process.

At a considerable distance from the hole *z*, place a double convex lens, fig. 5, whose focal length is equal to half that distance, and place the prism *x* behind the lens; at a distance behind the lens, equal to the distance of the lens from the hole, will be formed a spectrum, the length of whose rectilinear sides is the same as before, but its breadth much less; for the undiminished breadth was equal to a line subtending, at the distance of the spectrum from the hole, an angle equal to the apparent diameter of the sun, together with a line equal to the diameter of the hole; but the reduced breadth is equal to the diameter of the hole only. The image of the hole formed by the lens, at the distance of double its focal length, is equal to the hole; therefore its several images in the different kinds of rays are equal to the same, *i. e.* the breadth of the reduced spectrum is equal to the diameter of the hole.

A prism placed in a horizontal position would project the ray into an oblong form: apply another horizontal prism, similar to the former, to receive the refracted light emerging from the first; and having its refracted angle turned the contrary way from that of the former, the light, after passing through both prisms, will assume a circular form, as if it had not been at all refracted.

If the light emerging from the first prism be received by a second, whose axis is perpendicular to that of the former, it will be refracted by this transverse prism into a position inclined to the former, the red extremity being least, and the violet most removed from its former position; but it will not be at all altered in breadth.

Close to the prism A, fig. 6, place a perforated board *ab,* and let the refracted light, having passed through the small hole, be received on a second board *cd,* parallel to the first, and perforated in like manner: behind that hole in the second board, place a prism, with its refracting angle downward; turn the first prism slowly about its axis, and the light will move up and down the second board; let the colours be transmitted successively, and mark the places of the different coloured rays on the wall after their refraction by the second prism, the red will appear lowest, the violet highest, the rest in the intermediate places in order. Here, then, the light being very much simplified, and the incidences of all the rays on the second prism exactly the same, the red was least refracted, the violet most, &c.

The permanency of these original colours appears from hence, that they suffer no manner of change by any number of refractions, as is evident from the last mentioned experiment; nor yet by reflexion; for if any coloured body be placed in simplified homogeneous light, it will always appear of the same colour of the light in which it is placed, whether that differ from the colour of the body or not; *e. g.* if ultramarine and vermilion be placed in red light, both will appear red; in a green light, green; in a blue light, blue, &c. It is, however, to be allowed, that a body appears brighter when in a light of its own colour than in another; and from this we see that the colours of natural bodies arise from an aptitude in them to reflect some rays more copiously and strongly than others; but lest this phenomenon should produce a doubt of the constancy of the primary colours, it is proper to assign the reason of it, which is this: that when placed in its own coloured light, the body reflects the rays of the predominant colour more strongly than any of those intermixed with it; therefore the proportion of the rays of the predominant colour to those of the others, in the reflected light, will be greater than in the incident light; but when the body is placed in a light of a different colour from its own, for a similar reason the contrary effect will follow; *i. e.* the proportion of the predominant colour to the others will be less in the reflected than in the incident light, and therefore as its splendour would be greater in the former case, and would be less in the latter than if all the rays were equally reflected, the splendour of the predominant colour will be much greater in the former case than in the latter.

White is compounded of all the primary colours mixed in their due proportions; for if a solar ray be separated by the prism into its component parts, and at a proper distance a lens be so placed as to collect the diverging coloured rays again into a focus, a paper placed perpendicularly to the rays in this point will exhibit whiteness.

The following is a very pleasing and satisfactory method of illustrating this fact.

Draw two concentric circles, fig. 7, on a piece of stiff card-paper; from the centre draw the lines ABCDEFG, to the circumference of the outer circle, making them at the distance from each other in degrees as expressed in the figure. Then between the two circles paint the space A G red, inclining to orange near G; G F orange, inclining to yellow near F; FE yellow, inclining to green near E; ED green, inclining to blue near D;

DC blue, inclining to indigo near C; CB indigo, inclining to violet near B; and BA violet, inclining to a soft red near A.

Let all that part of the card within the inner circle be painted black. If now an axis be passed through the centre of the card, and the card made to revolve very rapidly upon it, the whole of the colours will appear so blended together as to present the appearance of a white ring, inclining a little to grey. Any of these colours may be made by mixing together the two contiguous prismatic colours.

Though seven different colours are distinguishable in the prismatic spectrum, yet upon examining the matter with more accuracy, we shall see that there are, in fact, only three original colours, red, blue, and yellow; for the orange being situated between the red and yellow, is only the mixture of these two: the green, in like manner, arises from the blue and yellow; and the violet from the blue and red.

As the colour of a body, therefore, proceeds from a certain combination of the primary rays which it reflects, the combination of rays flowing from any point of an object will, when collected by a glass, exhibit the same compound colour in the corresponding point of the image. Hence appears the reason why the images formed by glasses have the colours of the object which they represent.

Of Vision.

The eye is nearly of a spherical shape, and is composed of three different substances, called, 1. The aqueous, P, fig. 8. 2. The crystalline, R; and 3, the vitreous humours, V, enclosed by three principal coats, which are formed by the expansion of the different component parts of the optic nerve, *viz.* the sclerotica, SS. 2. The choroides, DD; and 3. The retina, TT. The sclerotica is outermost; it is very strong, and the fore part, which is transparent, and somewhat prominent, is called the cornea, C. The choroides is next in order, and has a circular perforation, P, called the pupil, immediately behind the middle of the cornea: the part II of the choroides, visible behind the cornea, is flat; it is called the iris, or uvea, and is differently coloured in different persons.

The retina is the inmost coat; it extends round the eye till it meets the ciliary ligaments. QQ, membranes proceeding from the choroides and attached to the capsula or filament, which incloses the crystalline humour, R. The crystalline is the most dense of the three humours, and is in the shape of a double convex lens, whose fore part has the less curvature; the cavity between the cornea and the crystalline is occupied by the aqueous humour, which has rather the least density of the three, and the space between the bottom of the eye and the crystalline is filled by the vitreous humour V.

Objects presented to the eye have their images painted on the back part of the retina, the rays of the incident pencils converging to their proper foci there by the refraction of the different humours; and for this office they are admirably adapted; for as the distance between the back and front of the eye is very small, and the rays of each of the pencils that form the image fall parallel, or else diverging on the eye, a strong refractive power is necessary for bringing them to their foci at the retina; but each of the humours, by its peculiar form and density, contributes to cause a convergence of the rays: the aqueous from its convex form; the crystalline by its double convexity and greater density than the aqueous; and the vitreous by a less density than the crystalline, joined to its concave form.

The structure of the eye is in general adapted to the reception of parallel rays, but as the distances of visible objects are various, so the eye has powers of accommodating itself to rays proceeding from different distances by altering the distances of the crystalline from the retina, which is done by the action of the ciliary ligaments.

Defective sight arises from an incapacity of altering the position of the crystalline within the usual limits. 1. When it cannot be brought close enough to the cornea, near objects appear indistinct; to this defect people in years are generally subject. 2. Where the crystalline cannot be drawn sufficiently near to the retina, remote objects appear indistinct; this is the defect under which short-sighted people labour. In each of these cases the images of the different points in the object would be diffused over small circles on the retina; and so being intermixed and confounded with each other, would there form a very confused picture of the object; for in the former case, the image of any point would be formed behind the retina, as the refraction of the eye is not sufficiently strong to bring the rays (diverging so much as they do in proceeding from a near point) to a focus at the retina. This defect will therefore be remedied by a convex glass, which makes the point whence the rays now proceed more distant than the object: therefore the rays falling on the eye will now diverge less than before, or else be parallel, and will of course be brought to a nearer focus, viz. at the retina.

In the latter case, the image is formed before the retina, because the refractive power of the eye is too great to permit rays so little diverging (as they do in proceeding from a distant point) to reach the retina before they are collected into a focus; in this case the defect is supplied by a concave glass, which makes the point whence the rays diverge nearer than the object: consequently, the rays falling on the eye will now diverge more than before, so as when refracted through the humours not to come to their focus before they reach the retina. Therefore spectacles are constructed concave for short-sighted, and convex for long-sighted people.

Of Optical Instruments.

From what has been stated concerning vision, the principle of the single microscope will be easily understood. Since the eye cannot have a distinct perception of any object at a nearer distance than six or eight inches, and since there are many objects which at that distance must be wholly imperceptible, or at best appear as points, an instrument which can render them visible is a very desirable attainment.

The most powerful single microscopes are very small globules of glass, which any curious person may make for himself by melting the ends of fine threads of glass in the flame of a candle; or by taking a little fine powdered glass on the point of a very small needle, and melting it into a globule in that way. It was with such microscopes as these that Lewenhoeck made all his wonderful discoveries, most of which are deposited in the British Museum.

The double or compound microscope differs from the preceding in this respect, that it consists of at least two lenses, by one of which an image is formed within the tube of the microscope; and this image is viewed through the eye-glass, instead of the object itself as in the single microscope. In this respect the principle is analogous to that of the telescope, only that, as the latter is intended to view distant objects, the object-lens is of a long focus, and consequently of a moderate magnifying power, and the eye-glass of a short focus, which magnifies considerably the image made by the object-lens. Whereas the microscope being intended only for minute objects, the object-lens is consequently of a short focus, and the eye-glass in this case is not of so high a magnifying power.

A single figure will serve to explain the principles on which all these instruments are constructed. Suppose therefore L N, fig. 9, to be the object-lens, and F G to be the eye-glass. The object O B is placed a little beyond the principal focus of L N. The cones or pencils of rays then proceeding from the different points of the object are by the lens made to converge to their respective foci, and form an inverted image of the object at P Q. This image is seen through the eye-glass F G, and the rays of each pencil will proceed in a parallel direction to the pupil of the eye.

The solar microscope is a kind of camera obscura, which, in a darkened chamber, throws the image on a wall or screen. It consists of two lenses fixed opposite a hole in a board or window-shutter; one, which condenses the light of the sun upon the object (which is placed between them), and the other, which forms the image. There is also a plain reflector placed without, moved by a wheel and pinion, which may be so regulated as to throw the sun's rays upon the outer lens. Mr. Adam's most ingenious invention, the lucernal microscope, is also to be considered as a kind of camera obscura; only the light in this latter case proceeds from a lamp, instead of from the sun, which renders it convenient to be used at all times. But for a description of this elegant and most amusing instrument, we must refer to his Microscopical Essays.

From what has been said on the nature of the compound microscope, the principle of the telescope may be easily understood. Telescopes are, however, of two kinds: the one depending on the principle of refraction, and called the dioptric-telescope; the other on the principle of reflexion, and therefore termed the reflecting telescope.

The parts essential to a dioptric-telescope are, the two lenses A D and E Y, fig. 10. As in the compound microscope, A D is the object-glass, and E Y is the eye-glass; and these glasses are so combined in the tube, that the focus F of the one is exactly coincident with the focus of the other.

Let O B then represent a very distant object, from every point of which pencils of rays will proceed so little diverging to the object-lens A D, that they may be considered as nearly parallel; I M will then be the image which would be formed on a screen by the action of the lens A D. For supposing O A and B D two pencils of rays proceeding from the extreme points of the object, they will unite in the focal point F, and intersect each other. But the point F is also the focus of the eye-glass EY; and therefore the pencil of rays, instead of going on to diverge, will pass through it in nearly a parallel direction, so as to cause distinct vision. It is then plain that, as in the compound microscope, it is the image which is here contemplated; and this will account for the common sensation when people say the object is brought nearer by a telescope. For the rays, which after crossing proceed in a divergent state, fall upon the lens EY, as if they proceeded from a real object situated at F. All that is effected by a telescope then is, to form such an image of a distant object, by means of the object-lens, and then to give the eye such assistance as is necessary for viewing that image as near as possible; so that the angle it shall subtend at the eye shall be very large compared with the angle which the object itself would subtend in the same situation. This is effected by means of the eye-glass, which refracts the pencils of rays, so that they may be brought to their several foci by the humours of the eye, as has been described. To explain clearly, however, the reason why it appears magnified, we must again have recourse to the figure. O B being at a great distance, the length of the telescope is inconsiderable with respect to it. Supposing, therefore, the eye viewed it from the centre of the object-glass C, it would see it under the angle O C B: let O C and B C then be produced to the focus of the glass, they will then limit the image I M formed in the focus. If then two parallel rays are supposed to proceed to the eye-glass E Y, they will be converged to its focus H, and the eye will see the image under the angle E H Y. The apparent magnitude of the object seen by the naked eye is, therefore, to that of the image which is seen through the telescope, as the magnitude of the angle O C B, or I C M, to that of E H Y, or I G M. Now the angle I G M is to I C M as C F to F G; that is, as the focal length of the object-glass to that of the eye-glass.

The magnifying power of these glasses may be augmented to a considerable degree, because the focal length of the object-glass, with respect to that of the eye-glass, may be greatly increased. This, however, would require a tube of immense length; because an eye-glass of a very short focus would cause such a dispersion of the rays of light, particularly towards the edges of the glass, that the view would be intercepted by the prismatic colours.

Another manifest defect in these telescopes is, that the image appears inverted; this, however, is of no consequence with respect to the heavenly bodies; and on this account it is still used as an astronomical telescope. One of almost a similar construction is also used on board of ships as a night-glass, to discover rocks in the ocean, or an enemy's fleet. Notwithstanding the inconvenience of exhibiting the objects inverted, more glasses than two cannot be employed, from the paucity of light; and habit soon enables the persons who use them to discern objects with tolerable distinctness.

The brightness of the appearance through any of these telescopes or microscopes depends chiefly on the aperture of the object-glass. For if the whole of that glass was covered except a small aperture in the middle, the magnitude of the image would not be altered; but fewer rays of every pencil being admitted, the object would appear obscure. In few words, the apparent distinctness or confusion of any object, viewed through glasses, depends on the mutual inclinations of the rays in any one pencil to each other when they fall on the eye; the apparent magnitude depends upon the inclination of the rays of different pencils to each other; the apparent situation depends upon the real situation of the extreme pencils; and the apparent brightness or obscurity, depends on the quantity of rays in each pencil. The well-known property in concave specula of causing the pencils of rays to converge to their foci, and there forming an image of an object that may be opposed to them, gave rise to the reflecting telescope. In this the effect is precisely the same as that produced by the dioptric telescope; only that in the one case it is produced by reflected, and in the other by refracted, light. Reflecting telescopes are made in various forms; and those principally in use in this country are distinguished by the names of their respective inventors, and are called the Newtonian, Gregorian, and Herschelian telescopes. The reflecting telescope on the Gregorian principle, which is the most common, as it is found to be the most convenient, is constructed in the following manner:—At the bottom of the great tube, fig. 11, T T T T, is placed a large concave mirror D U V F, whose principal focus is at *m*: and in the middle of this mirror is a round hole P, opposite to which is placed the small mirror L, concave toward the great one; and so fixed to a strong wire M that it may be removed further from the great mirror, or nearer to it by means of a long screw in the inside of the tube, keeping its axis still in the same line P *m n* with that of the great one. Now, since in viewing a very remote object, we can scarcely see a point of it but what is, at least, as broad as the great mirror, we may consider the rays of each pencil, which flow from every point of the object, to be parallel to each other, and to cover the whole reflecting surface D U V F. But to avoid confusion in the figure, we shall only draw two rays of a pencil flowing from each extremity of the object into the great tube; and trace their progress through all their reflexions and refractions to the eye *f* at the end of the small tube *t t*, which is joined to the great one.

Let us then suppose the object AB to be at such a distance, that the rays C may flow from its upper extremity A, and the rays E from its lower extremity B; then the rays C falling parallel upon the great mirror at D, will be thence reflected converging in the direction D G: and by crossing at I in the principal focus in the mirror, they will form the lower extremity of the inverted image I K, similar to the upper extremity A of the object A B; and passing on to the concave mirror L (whose focus is at *n*), they will fall upon it at *g*, and be thence reflected, converging in the direction *g* N, because *g m* is longer than *g n*: and passing through the hole P in the large mirror, they would meet somewhere about *r*, and form the upper extremity *a* of the erect image *ab*, similar to the upper extremity A of the object AB.

But by passing through the plano convex-glass R in their way, they form that extremity of the image at *a*. In the same manner the rays E, which come from the bottom of the object AB, and fall parallel upon the great mirror at F, are thence reflected, converging to its focus; where they form the upper extremity I of the inverted image I K, similar to the lower extremity B of the object A B: and thence passing on to the small mirror L, and falling upon it at *h*, they are thence reflected in the converging state *h* O; and going on through the hole P of the great mirror, they would meet somewhere about *q*, and form there the lower extremity *b* of the erect image *a b*, similar to the lower extremity B of the object A B; but by passing through the convex glass R in their way, they meet and cross sooner, as at *b*, where that point of the erect image is formed. The like being understood of all those rays which flow from the intermediate points of the object between A and B, and enter the tube T T, all the intermediate points of the image between *a* and *b* will be formed; and the rays passing on from the image through the eye-glass S, and through a small hole *e* in the end of the lesser tube *t t*, they enter the eye *f*, which sees the image *a b* (by means of the eye-glass) under the large angle *c e d*, and magnified in length under that angle from *c* to *d*.

In the best reflecting telescopes, the focus of the small mirror is never coincident with the focus *m* of the great one, where the first image I K is formed, but a little beyond it (with respect to the eye) as at *n*; the consequence of which is, that the rays of the pencils will not be parallel after reflexion from the small mirror, but converge so as to meet in points about *q*, *e*, *r*: where they would form a larger upright image than *ab*, if the glass R was not in their way, and this image might be viewed by means of a single eye-glass properly placed between the image and the eye: but then the field of view would be less, and consequently not so pleasant; for that reason the glass R is still retained, to enlarge the scope or area of the field.

To find the magnifying power of this telescope, multiply the focal distance of the great mirror by the distance of the small mirror from the image next the eye, and multiply the focal distance of the small mirror by the focal distance of the eye-glass; then divide the product of the former multiplication by that of the latter, and the quotient will express the magnifying power. The difference between the Newtonian and Gregorian telescope is, that in the former the spectator looks in at the side through an aperture upon a plane mirror, by which the rays reflected from the concave mirror are reflected to the eye-glass; whereas in the latter the reader will see that he looks through the common eye-glass, which is in general more convenient.

The immensely powerful telescopes of Dr. Herschel are of a still different construction. This assiduous astronomer has made several specula, which are so perfect as to bear a magnifying power of more than six thousand times in diameter on a distant object. The object is reflected by a mirror, as in the Gregorian telescope, and the rays are intercepted by a lens at a proper distance, so that the observer has his back to the object, and looks through the lens at the mirror. The magnifying power will in this case be the same as in the Newtonian telescope; but there not being a second reflector, the brightness of the object viewed in the Herschelian is greater than that in the Newtonian or Gregorian telescope. In conclusion, Sir Isaac Newton's excellent maxim must not be omitted: "The art," says he, "of constructing good microscopes and telescopes may be said to depend on the circumstance of making the last image as large, and distinct, and luminous, as possible."

The camera obscura is an instrument used to facilitate the delineation of landscapes. It is constructed in the following manner: A C, fig. 1, plate X. represents a box of about a foot and a half square, shut on every side, except D C; O P is a smaller box placed on the top of the greater; N N is a double convex lens, whose axis makes an angle of 45° with B L, a plane mirror fixed in the box O P; the focal length of the lens is nearly equal to $C S + S T$, *i. e.* to the sum of the distances of the lens from the middle of the mirror and of the middle of the mirror from the bottom of the larger box.

The lens being turned towards the prospect, would form a picture of it, nearly at its focus; but the rays being intercepted by the mirror, will form the picture as far before the surface as the focus is behind it; *i. e.* at the bottom of the larger box, a communication being made between the boxes by the vacant space Q O. The draughtsman then putting his head and hands into the box through the open side, D C, and drawing a curtain round to prevent the admission of the light, which would disturb the operation, may trace a distinct outline of the picture that appears on the bottom of the box.

The late Dr. Wollaston invented a portable instrument for drawing in perspective, to which he gave the name of the *camera lucida.*

The instrument, as represented in the figures, may be used either with the small round glass turned up in front, fig. 2, or with the larger glass turned up level underneath the instrument, fig. 3, *(seen from above).* But those who are short-sighted can only use the former, and persons that are long-sighted must use the latter.

The prism is next to be turned upon its pin, till the transparent rectangular face be placed opposite to the objects to be delineated, when the upper black surface of the eye-piece E will be on the top of the instrument; and through the aperture in this, the artist is to look perpendicularly downwards at his paper.

The black eye-piece E is moveable, and in ordinary circumstances is to be in such a position, that the edge of the small transparent part at the back of the prism shall intercept about half the eye-hole. The artist then, looking through the eye-hole directly downwards at his paper, should see the object he wishes to draw, apparently distributed over the paper. For, since his eye is larger than the eye-hole, he sees through both halves of the hole at the same time, without moving his head. He sees the paper through the nearer half, and sees the object at the same time through the farther half, apparently in the same direction, by means of reflexion, through the prism.

The position of the *eye-hole* is the circumstance, above all others, necessary to be attended to in adjusting the camera lucida for use; for on the due position of this hole depends the possibility of seeing both the pencil and the objects distinctly at the same time.

If the eye-hole be moved, so that nearly the whole of its aperture be over the paper, and a very small portion over the prism, then the pencil and paper will be very distinctly seen; but the objects to be delineated, very dimly. If, on the other hand, the aperture be mostly over the prism, and but a small portion over the paper, then the objects will be seen distinctly, but the pencil and paper will be very faint. But there will always be an intermediate position (varying according as the objects or the paper happen to be most illuminated) in which both will be sufficiently visible for the purpose of delineation, though not quite so clear as to the naked eye. This intermediate position is easily found with a little practice.

In copying drawings, the copy will be larger or smaller than the original, according as the prism is more or less distant from the paper than it is from the drawing to be copied. Thus, if the drawing be two feet from the prism, and the paper only one foot, the copy will be half the size of the original. If the drawing be at one foot, and the paper three feet distant, the copy will be three times as large as the original, and so for all other distances

The magic lantern is an optical instrument invented by Athanasius Kircher, the use of which is to magnify small paintings on glass. The construction and use of this instrument will be seen by inspecting fig. 4. A B C D represents a tin lantern, from one side of which there proceeds the square tube *b n k l m c*, consisting of two parts: the outermost of which, *n k l m*, slides over the other, so that the whole tube may be lengthened or shortened by that means. In the end of the arm *n k l m*, is fixed a convex lens, *k l*; about *d e* there is an opening for admitting an object, as *d e*, painted in dilute and transparent colours, on a plane of thin clear glass, which object is there placed in an inverted position. A single or double convex lens *b h c* is employed for casting the light from the flame of the candle or lamp *a*, very strongly on the picture *d e*. If the object *d e* be placed further from the lens *k l* than its focus, a distinct image of the object will be projected by the glass *k l* upon the opposite white wall or screen F H, at *f g*, and it will be in an erect position.

The apartment in which the exhibition is made must be completely darkened. To increase the light a concave mirror O P is generally placed behind the lamp, having the flame as nearly as possible in its focus.

The exhibition called the phantasmagoria differs from the magic lantern only in the following particulars, viz. the sliders are made perfectly opaque except where the figures are introduced; and the screen on which the images are thrown is placed between the lantern and the spectators.

Several methods of preparing muslin for the phantasmagoria screen have been tried, but the best, and certainly the simplest and cheapest, is to dip the screen in clean water, just before using it. This mode renders it beautifully transparent, and the colours on the figures appear remarkably brilliant. The phantasmagoria is finely adapted for exhibiting telescopic views of the heavenly bodies, for which purpose it is now much used by public lecturers.

For a description of an improved apparatus of this kind the reader is referred to Dr. Young's Lectures on Natural Philosophy, vol. i. p. 426. 785.

Of the Rainbow and other Phenomena of Light.

Since the rays of light are found to be decompounded by refracting surfaces, we can no longer be surprised at the changes produced in any object by the intervention of another. The vivid colours which gild the rising or the setting sun must necessarily differ from those which adorn its noon-day splendour. There must be the greatest variety which the liveliest fancy can imagine. The clouds will assume the most fantastic forms, or will lour with the darkest hues, according to the different rays which are reflected to our eyes, or the quantity absorbed by the vapours in the air. The ignorant multitude will necessarily be alarmed by the sights in the heavens; by the appearance at one time of three, at another of five suns; of circles of various magnitudes round the sun or moon; and thence conceive that some fatal change must take place in the physical or the moral world, some fall of empires, or tremendous earthquake; while the optician contemplates them merely as the natural and beautiful effects produced by clouds or vapour in various masses upon the rays of light.

One of the most beautiful and common of these appearances deserves particular investigation, as, when this subject is well understood, there will be little difficulty in accounting for others of a similar nature, dependent on the different refrangibility of the rays of light. Frequently when our backs are turned to the sun, and there is a shower either around us or at some distance before us, a bow is seen in the air, adorned with all or some of the seven primary colours.

The appearance of this bow, in poetical language called the iris, and in common language the rainbow, was an inexplicable mystery to the ancients; and, though now well understood, continues to be the subject of admiration to the peasant and the philosopher. We are indebted to Sir Isaac Newton for the explanation of this appearance; and by various easy experiments we may convince any man that his theory is founded on truth. If a glass globe is suspended in the strong light of the sun, it will be found to reflect the different prismatic colours exactly in proportion to the position in which it is placed; in other words, agreeably to the angle which it forms with the spectator's eye and the incidence of the rays of light. The fact is, that innumerable pencils of light fall upon the surface of the globe, and each of these is separated as by a prism. To make this matter still clearer, let us suppose the circle B A W, fig. 5, to represent the globe, or a drop of rain, for each drop may be considered as a small globe of water. The red rays, it is well known, are least refrangible; they will therefore be refracted, agreeably to their angle of incidence, to a certain point A in the most distant part of the globe; the yellow, the green, the blue, and the purple rays will each be refracted to another point. A part of the light, as refracted, will be transmitted, but a part also will be reflected; the red rays at the point A, and the others at certain other points, agreeably to their angle of refraction.

It is very evident that if the spectator's eye is placed in the direction of M W, or the course of the red-making rays, he will only distinguish the red colour; if in another situation, he will see only by the yellow rays; in another by the blue, &c.: but as in a shower of rain there are drops at all heights and all distances, all those that are in a certain position with respect to the spectator will reflect the red rays, all those in the next station the orange, those in the next the green, &c.

To avoid confusion, let us imagine only three drops of rain, and three degrees of colours in the section of a bow, fig. 6. It is evident that the angle C E P is less than the angle B E P, and that the angle A E P is the greatest of the three. This largest angle then is formed by the red rays, the middle one consists of the green, and the smallest is the purple. All the drops of rain, therefore, that happen to be in a certain position to the eye of the spectator will reflect the red rays, and form a band or semicircle of red; those again in a certain position will present a band of green, &c. If he alters his station, the spectator will still see a bow, though not the same bow as before; and if there are many spectators they will each see a different bow, though it appears to be the same.

There are sometimes seen two bows, one formed as has been described, the other appearing externally to embrace the primary bow, and which is sometimes called a secondary or false bow, because it is fainter than the other; and what is most remarkable is, that in the false bow the order of the colours appears always reversed.

In the true or primary bow we have seen that the rays of light arrive at the spectator's eye after two refractions and one reflexion; in the secondary bow the rays are sent to our eyes after two refractions and two reflexions, and the order of the colours is reversed, because in this latter case the light enters at the inferior part of the drop, and is transmitted through the superior.

Thus fig. 7, the ray of light which enters at B is refracted to A, whence it is reflected to P, and again reflected to W, where, suffering another refraction, it is sent to the eye of the spectator. The colours of this outer bow are fainter than those of the other, because the drop being transparent, a part of the light is transmitted, and consequently lost, at each reflexion.

The phenomenon assumes a semicircular appearance, because it is only at certain angles that the refracted rays are visible to our eyes. The least refrangible, or red rays, make an angle of 42 degrees, two minutes, and the most refrangible, or violet rays, an angle of 40 degrees, 47 minutes. Now if a line is drawn horizontally from the spectator's eye, it is evident that angles formed with this line, of a certain dimension in every direction, will produce a circle; as will be evident by only attaching a cord of a given length to a certain point, round which it may turn as round its axis, and in every point will describe an angle with the horizontal line, of a certain and determinate extent.

Let H O, for instance, fig. 5, represent the horizon, B W a drop of rain at any altitude, S B a line drawn from the sun to the drop, which will be parallel to a line S M drawn from the eye of the spectator to the sun. The course of part of the decompounded ray S B may be first by refraction from B to A, then by reflexion from A to W, lastly by refraction from W to M. Now all drops which are in such a situation that the incident and emergent rays S B, M W, produced through them make the same angle S N M, will be the means of exciting in the spectators the same idea of colour. Let M W turn upon H O as an axis, till W meets the horizon on both sides, and the point W will describe the arc of the circle: and all the drops placed in its circumference will have the property we have mentioned, of transmitting to the eye a particular colour. When the plane H M W A is perpendicular to the horizon, the line M W is directed to the vertex of the bow, and W K is its altitude.

This altitude depends on two things, the angle between the incident and emergent rays, and the height of the sun above the horizon; for since S M is parallel to S N, the angle S N M is equal to N M I: but S M H, the altitude of the sun, is equal to K M I; therefore the altitude of the bow W M K, which is equal to the difference between W M I and K M I, is equal to the difference between the angles made by the incident and emergent rays and the altitudes of the sun.

The angle between the incident and emergent rays is different for the different colours, as was already intimated; for the red, or least refrangible, rays, it is equal to 42° 2′; for violet, or most refrangible, it is equal to 40° 17′; consequently when the sun is more than 40° 2′ above the horizon, the red colour cannot be seen; when it is above 40° 17′ the violet colour cannot be seen.

The secondary bow is made in a similar manner; but the sun's rays suffer, in this case, two reflexions within the drop. The ray S B, fig. 7, is decompounded at B; and one part is refracted to A, thence reflected to P, and from P reflected to W, where it is refracted to M. The angle between the incident and emergent rays S M N is equal as before to N M I; and N M K, the height of the bow, is equal to the difference between the angle made by the incident and emergent rays and the height of the sun. In this case the angle S N M for the red rays is equal to 50° 7′, and for the violet rays it is equal to 54° 7′; consequently the upper part of the secondary bow will not be seen when the sun is above 54° 7′ above the horizon, and the lower part of the bow will not be seen when the sun is 50° 7′ above the horizon.

In the same manner innumerable bows might be formed by a greater number of reflexions within the drops; but as the secondary is so much fainter than the primary, that all the colours in it are seldom seen, for the same reason a bow made with three reflexions would be fainter still, and, in general, altogether imperceptible. Since the rays of light, by various reflexions, are thus capable of forming by means of drops of rain the bows which we so frequently see in the heavens, it is evident that there will be not only solar and lunar bows, but that many striking appearances will be produced by drops upon the ground, or air on the agitated surface of the water. Thus, a lunar bow will be formed by rays from the moon, effected by drops of rain; but as its light is very faint in comparison with that of the sun, such a bow will very seldom be seen, and the colours of it, when seen, will be faint and dim.

The marine or sea-bow is a phenomenon sometimes observed in a much agitated sea; when the wind, sweeping part of the top of the waves, carries them aloft, so that the sun's rays, falling upon them, are refracted, &c. as in a common shower, and paint the colours of the bow.

Rohault mentions coloured bows on the grass, formed by the refraction of the sun's rays in the morning dew.

Dr. Langwith, indeed, once saw a bow lying on the ground, the colours of which were almost as lively as those of the common rainbow. It was extended several hundred yards. It was not round, but oblong, being, as he conceived, the portion of an hyperbola.

The drops of rain descend in a globular form, and thence we can easily account for the effects produced by them on the rays of light: but in different states of the air, instead of drops of rain, vapour falls to the earth in different forms of sleet, snow, and hail. In the two latter states there cannot be a refraction of the rays of light; but in the former state, when a drop is partly in a congealed and partly in a fluid form, the rays of light will be differently affected, both from the form of the drop and its various refracting powers.

The halo, or corona, is a luminous circle surrounding the sun, the moon, a planet, or a fixed star. It is sometimes quite white, and sometimes coloured like the rainbow. Those which have been observed round the moon or stars are but of a very small diameter: those round the sun are of different magnitudes, and sometimes immensely great. When coloured, the colours are fainter than those of the rainbow, and appear in a different order, according to their size. In those which Sir Isaac Newton observed in 1692, the order of the colours, from the inside next the sun, was, in the innermost, blue, white, red; in the middle, purple, blue, green, yellow, pale red; in the outermost, pale blue, and pale red. Huygens observed one red next the sun, and pale blue at the extremity. Mr. Weidler has given an account of one yellow on the inside, and white on the outside. In France one was observed, in which the order of the colours was white, red, blue, green, and a bright red on the outside.

Artificial coronas may be made in cold weather, by placing a lighted candle in the midst of a cloud of steam; or if a glass window is breathed upon, and the flame of a candle placed at some distance from the window, while the operator is also at the distance of some feet from another part of the window, the flame will be surrounded with a coloured halo.

The parhelia, or mock suns, are the most splendid appearances of this kind

The parhelia generally appear about the size of the true sun, not quite so bright, though they are said sometimes to rival their parent luminary in splendour. When there are a number of them they are not equal to each other in brightness. Externally they are tinged with colours like the rainbow. They are not always round, and have sometimes a long fiery tail opposite the sun, but paler towards the extremity. Dr. Haller observed one with tails extending both ways. Mr. Weidler saw a parhelion with one tail pointing up, and another downwards, a little crooked; the limb which was farthest from the sun being of a purple colour, the other tinged with the colours of the rainbow.

Coronas generally accompany parhelia: some coloured, and others white. There is also, in general, a very large white circle, parallel to the horizon, which passes through all the parhelia; and, if it was entire, would go through the centre of the sun: sometimes there are arches of smaller circles concentric to this, and touching the coloured circles which surround the sun; they are also tinged with colours, and contain other parhelia.

One of the most remarkable appearances of this kind was that which was observed at Rome by Scheiner, as intimated above; and this may serve as a sufficient instance of the parhelion.

This celebrated phenomenon is represented in fig. 8, in which A is the place of the observer, B his zenith, C the true sun, and A B a plane passing through the observer's eye, the true sun, and the zenith. About the sun C there appeared two concentric rings, not complete, but diversified with colours. The lesser of them, D E F, was fuller, and more perfect; and though it was open from D to F, yet those ends were perpetually endeavouring to unite, and sometimes they did so. The outer of these rings was much fainter, so as scarcely to be discernible. It had, however, a variety of colours, but was very inconstant. The third circle, K L M N, was very large, and entirely white, passing through the middle of the sun, and every where parallel to the horizon. At first this circle was entire; but towards the end of the phenomenon it was weak and ragged, so as hardly to be perceived from M towards N.

In the intersection of this circle and the outward iris G K I, there broke out two parhelia, or mock suns, N and K, not quite perfect, K being rather weak, but N shone brighter and stronger. The brightness of the middle of them was something like that of the sun; but towards the edges they were tinged with colours like those of the rainbow, and they were uneven and ragged. The parhelion N was a little wavering; and sent out a spiked tail N P, of a colour somewhat fiery, the length of which was continually changing.

The parhelia at L and M, in the horizontal ring, were not so bright as the former, but were rounder, and white, like the circle in which they were placed. The parhelion N disappeared before K; and while M grew fainter, K grew brighter, and vanished the last of all.

It is to be observed further, that the order of the colours in the circles D E F, G K N, was the same as in the common halos, namely, red next the sun; and the diameter of the inner circle was also about 45°, which is the usual size of a halo.

Parhelia have been seen for one, two, three, and four hours together; and in North America they are said to continue some days, and to be visible from sunrise to sunset. When they disappear it sometimes rains, or snow falls in the form of oblong spiculæ.

Mr. Wales says, that at Churchill, in Hudson's Bay, the rising of the sun is always preceded by two long streams of red light. These rise as the sun rises; and, as they grow longer, begin to bend towards each other, till they meet directly over the sun, forming there a kind of parhelion, or mock-sun.

These two streams of light, he says, seem to have their source in two other parhelia which rise with the true sun; and in the winter season, when the sun never rises above the haze or fog which he says is constantly found near the horizon, all these accompany him the whole day, and set with him in the same manner as they rise. Once or twice he saw a fourth parhelion under the true sun; but this, he adds, is not common.

The cause of these is apparently the reflexion of the sun's light and image from the thick and frozen clouds in the northern atmosphere, accompanied also with some degree of refraction.

CHAPTER X.

ELECTRICITY.

This term, which is derived from the Greek word ηλεκτρον signifying *amber*, is now generally applied to that science which investigates the attractions and repulsions, the emission of light, and explosions, which are produced, not only by the friction of vitreous, resinous, and metallic surfaces, but by the heating, cooling, evaporation, and mutual contact of a vast number of bodies.

It is common for writers on the subject of electricity to give at least a sketch of the history of the science; but as we are necessarily compelled to study the utmost brevity in a work like the present, we must be excused entering on such a detail; simply remarking, that the electrical phenomena constitute the first physical fact recorded in the history of science.

Neither shall we here attempt a discussion on the nature of the electric substance; since, at the present hour, the most rational theories before the public are at least but hypothetical; although it must be allowed, that the means of investigation which are now at the command of scientific men; the persevering diligence with which those means are employed; and the success which seems to crown their labours, unite in announcing the near approach of some discovery that will effect what has baffled the ingenuity of philosophers for nearly two thousand years.

The first thing that demands attention on this subject is the proper management of the electrical machine. Although it must require considerable practice to enable a person to perform electrical experiments with neatness and success, yet the path to this very desirable end may, we conceive, be much shortened by a strict attention to suitable directions.

OF ELECTRICAL MACHINES.

There are two forms of the electrical machine, viz. the cylindrical, which is the most common, and the cheapest form in which the machine can be made; and the plate machine, which has decidedly the advantage of the cylindrical in point of elegance, and also in power, although some prefer the latter on account of the facility which it affords for producing negative electricity.

Fig. 1, plate XI. represents the cylindrical machine in the simplest and most convenient form in which it can be constructed. A A A A is the board on which the supporters and pillars are erected, and by which the machine is made fast with cramps to the table. B B B B are two wooden pillars or supporters, having their lower ends mortised into the board A A A A, and in the upper ends of these the axis of the glass cylinder C C C C turns. D D is the winch by which the cylinder is turned on its axis. E E is a piece of wood, a part of which slides into a groove under the board A A A A, and is made fast by the thumb-screw *f.* G G is a glass pillar, which is fixed to the wood E E, and supports what is called the negative conductor and rubber H H. I I is another piece of wood, which slides in a similar groove under the board A A A A, and is made fast by the thumb-screw *j.* K K is a glass pillar fixed into the wood I I, and supports the prime conductor L L; to this conductor a number of metallic points are attached, to collect the fluid from the surface of the cylinder, and lead it to the prime conductor. M M is a rod of brass inserted in the prime conductor, having a joint by which it may be raised or lowered, to suit the height of the apparatus; this rod is a most useful appendage to the prime conductor. To the upper part of the rubber a piece of black silk is attached, which proceeds from thence over the top of the cylinder, to within about half an inch of the points of the wires inserted in the prime conductor; by which means the fluid that is brought into action by the attrition of the cyclinder and rubber is prevented from being dissipated in the air, and carried round with the cylinder to the prime conductor. The action of the silk on the cylinder tends very much to increase the excitation of the machine, as may be seen by removing the cushion a little back from the cylinder, and leaving the silk to act upon it alone, in which case the excitation will often be found to be scarcely less than when the rubber is also in contact with the cylinder.

The plate electrical machine, represented fig. 2, was invented by Dr. Ingenhouz, and has been perfected by Mr. Cuthbertson. It consists of a circular plate of glass, turning on an axis which passes through its centre; it is rubbed by two pairs of cushions fixed at opposite points of its periphery by elastic frames of thin mahogany, which are made to press the glass plate with the required degree of force, by means of regulating screws. A brass conductor, supported by glass, is fixed to the frame of the machine, with its branched extremities opposite each other, and near the extreme diameter of the plate, in a direction at right angles with the vertical line of the opposite cushions. The branched extremities of the conductor are furnished with pointed wires, which serve to collect the electricity from the surface of the excited plate. These machines are sometimes fitted up with two plates, which are fixed on the same axis, by which the power of two machines is combined in one, although the labour of turning such a machine is thereby augmented considerably; where a copious flow of electricity is required, two of these double plate machines may be used, or a single plate of large diameter. The motion of the machine must always be in the direction of the silk flaps that proceed from the rubbers.

The cylindrical machine, however, being at present in more common use than the plate machine, it is hoped the following remarks may be of use to those who possess such an instrument, and particularly to such as may be disposed to provide themselves with it for the sake of economy. A cylindrical electrical machine ought never to be less than ten inches in diameter: there are cylinders of six, seven, eight, and nine inches diameter, often neatly mounted, and sold by the philosophical instrument-makers, but they are of no manner of use for the purpose of experiment, and serve only as a kind of philosophical toy, for the amusement of children, and that too on a very narrow scale. To construct such machines, therefore, is an absolute waste of the materials. With a cylinder of ten inches, properly managed, a tolerable exhibition may be made, but the most convenient size is from twelve to sixteen, the length of the cylinder being in proportion.

The most powerful excitation of the machine is produced as follows. Let the machine be placed within the influence of a good fire, but not so near as to injure any of its parts by the action of the heat. With a flat round pointed knife spread a little amalgam evenly along the cushion, and return it to its place: turn the cylinder a few times round; then take off the cushion; and observe carefully those parts on its surface that have not been touched by the cylinder while revolving; on these parts put a little more amalgam, and repeat the process of turning the cylinder, and supplying the defective parts with amalgam, till every point of that part of the surface of the cushion which presses on the cylinder appears to be properly supplied with amalgam. Take now a piece of leather, about five or six inches square, and spread over one side of it a quantity of amalgam; throw back the silk flap, and, turning the machine gently round, apply the amalgamed side of the leather to the cylinder, for the space of two minutes or more, as circumstances may require, during which time the excitation will be observed to increase rapidly. The cylinder must next be wiped perfectly clean with an old silk handkerchief, and afterwards with a soft dry linen cloth. Let the cushion be again removed; and the amalgam which appears above and below the line of contact with the cylinder carefully scraped off, the silk flap wiped with the linen cloth, and the whole returned to its place and made fast. If now the cylinder be turned slowly round, streams of the electric fluid will be seen rushing from the silk flap round the lower part of the cylinder, attended with a hissing and snapping noise, while large brushes of the same, of several inches in length, may be observed flying off from the lower edge of the silk into the surrounding air. The machine is now fit for use, and may be fastened to the table, after which the whole of its parts are to be well wiped with a warm and dry linen cloth, to free them from dust.

The operator, however, must not expect this high and rich state of excitation to be of long duration. The cylinder will soon cool; dust will be attracted by the action of the machine; and the moisture produced in the air of the room by the breaths of his audience, will, by their united effects, render all his efforts to produce a copious supply of electricity entirely fruitless.

To remedy this defect, which gentlemen who deliver public lectures on electricity have often found to be a grievous one, provide a box of thin plate iron, ten or twelve inches long, four inches wide, and one inch and a half in depth, with a lid to fit very easily over it. In this box a piece of bar iron, of about six inches in length, three in breadth, and half an inch in thickness, after being heated in the fire to a dull red heat, is to be placed, the lid of the box put on, and the whole, on a suitable iron stand, placed under the cylinder, on the board of the machine, in a longitudinal direction. The radiation of heat from the iron will effectually preserve the equality of the temperature of the surrounding air for a considerable length of time, and indeed for any length of time required, since, by employing two bars of iron, the one may be kept in the fire while the other is in the box, and thus no other interruption in the course of the experiments will be necessary beyond what is occasioned by the changing of the irons. By this means the machine may be made to act in full vigour under the most disadvantageous circumstances. Whilst writing this article we have seen a proposal for remedying the difficulty we refer to, by placing a small spirit lamp under the rubber of the machine, and another under the conductor. This method may certainly, in some degree, prove beneficial; but it will be found to be in many respects inferior to the simple method here offered. In the first place, the radiation of heat will be neither so general nor so great; in the second place, the flame of a lamp or a candle absorbs the fluid; and in the third place, the *light*, which must necessarily be emitted from two spirit lamps, would prove highly detrimental to the effect of those experiments which require to be performed in darkness. To which may be added, the expense of the lamps, and the spirit to be consumed.' Where a plate machine of large dimensions is used, this additional article will not be required; for the great thickness of the glass renders it capable of retaining the heat much longer than can be done by a thin cylinder; for which reason it must be obvious that if cylinders were made much stronger than they generally are, their action would be effectual for a greater length of time than it is. Opinion, however, runs in favour of thin cylinders, but the consistency of such opinion remains to be shown.' It is well known that the old globular machines, which were made of thick glass, when once put in a state of powerful excitation, retain that state much longer than the modern thin cylinder will do under the same circumstances.

The best *amalgam* for electrical machines is thus made. Melt in an iron ladle two ounces of zinc with one ounce of tin, and while this mixture is in a fluid state, pour into it six ounces of mercury; let the whole be then put into an iron or wooden box, and agitated until it be quite cold. It must then be reduced to fine powder in a mortar, and mixed with sweet hog's lard, to the consistence of thick paste. This part of the process need not be performed till the amalgam is wanted for use.

OF ELECTRICAL APPARATUS.

The various articles of apparatus necessary for the exhibition of the most usual experiments in electricity are insulating stands, or supports of various forms, wires, fine brass chains, a few spare brass balls of different sizes that may be screwed on wires when wanted; a few pith balls, two or three glass tubes of about three quarters of an inch in diameter, and from three to five feet in length; a large stick of sealing-wax, and four or five coated jars of different sizes. Electrical apparatus may be multiplied to a very great extent; but the electrician who understands the construction of his apparatus can readily combine even a small portion of it in so many different ways, that he may save himself from an enormous expense by the exercise of his own ingenuity. No person, indeed, who is not competent to handle electrical apparatus with the skill of a workman, ought ever to venture beyond the most common-place experiments, at least where expense is any object.

The application of the apparatus to the purpose of experiment will best explain the nature of its different parts; and, in adopting this plan, we shall be enabled to give such an arranged view of the chief properties of the electrical fluid as may be of service in aiding the inexperienced electrician in making an orderly display, instead of a series of experiments which have no regular connexion, and in which, sometimes one property, and sometimes another, is illustrated.

Attraction and Repulsion.

1. Excite a glass tube, by rubbing it for a few seconds with a silk handkerchief that has a little amalgam spread upon that part of it which touches the tube; hold the excited tube over some small bits of leaf gold, placed on a metallic plate, or on a smooth table, and they will be immediately attracted by the tube, between which and the table they may be made to pass up and down with great rapidity for a considerable time.

2. Bring an excited tube near a small downy feather; the feather will be attracted by the tube, and will cling to it till it be saturated with the fluid; it will then be repelled, and may be kept floating about in the room, by occasionally approaching it with the tube, from which it will recede, so long as it retains the electricity which it carried off from the tube.

3. By a fine flaxen thread attach a large downy feather to the prime conductor of the machine; turn the cylinder gently round, and the fibres of the feather will repel each other; approach it with a brass ball, or with the closed hand, and it will endeavour to turn itself towards the ball or hand; but present a pointed wire to it, and it will instantly shrink from it back on the conductor, as if animated, which arises from its being suddenly deprived of its electricity by the point.

4. This experiment may be varied by inserting the brass stem of fig. 3 into one of the holes in the prime conductor. The action of the machine will cause the hairs on the head to diverge from each other, and to stand on end.

5. By means of a pointed wire projecting a few inches from the prime conductor, electrify the inside

of a large dry glass tumbler, then place it over about a dozen of small pith balls on a table, and the balls will be alternately attracted and repelled, at first with great rapidity, but the motion will become gradually more languid until it entirely cease. An instrument is constructed on purpose for this experiment, by which the dancing of the balls may be kept up for any length of time, as it may be connected with the conductor. See fig. 4.

6. Suspend from the conductor, by a brass chain, a circular plate of copper, and reaching to within an inch and a half, or two inches of the table. Directly under this plate, place another of the same form and a little larger on the table. Turn the machine, and the fluid will pass from the upper to the lower plate. If now small figures fancifully cut out of pasteboard, or pith of elder, be introduced between the plates, they will dance about with apparent vivacity, and sometimes appear to course round the edge of the lower plate. See fig. 5.

7. The *electrical bells* furnish a pleasing illustration of the attraction and repulsion of the electric matter. They are variously constructed, but the form exhibited fig. 6 is the simplest. The two outer bells are suspended by brass chains; the middle bell and the two clappers by fine silk threads. When the bells are attached to the conductor, and the machine is turned very slowly, the fluid will pass along the chains to the two outer bells, but will not pass along the silk to the clappers and middle bell. Thus the outer bells being charged with an extra quantity of electricity will attract the clappers, but the moment they touch the bells, they become charged, and are repelled with such force as to cause them to strike against the middle bell, on which they deposit their electricity, and are again attracted. By this means a constant ringing is kept up while the machine is turned. From the inside of the middle bell a brass chain passes to the table, for the purpose of conveying away the fluid deposited on it by the clappers.

Effect of Points on the Electric Fluid.

The effect of pointed conductors on the electric fluid may be illustrated by a great variety of pleasing experiments. The following are perhaps the most striking. 1. The *electrical fly*. Fig. 7 represents a light brass fly, consisting of fine wires proceeding from a common centre, and having their pointed ends turned back at right angles, and all in the same direction. If this fly be poised on its centre on a pointed wire inserted in the prime conductor, and the machine be put in action, a stream of fluid will issue from each point, and produce a loco-motion in the fly, propelling it in a direction contrary to that of the points: the points will of course appear luminous, and if the room be darkened, a beautiful circle of fire will be distinctly seen, formed by the revolution of the fly. On the same principle, motion is communicated to, 2. The *electrical orrery*. This instrument is represented by fig. 8. The ball S represents the sun, E the earth, and M the moon, connected by the wires *a c* and *b d*: *b* is the centre of gravity between the earth and moon.

These three balls and their connecting wires are supported on the sharp point of a wire A, which is inserted in a hole in the prime conductor, and must stand perfectly upright and steady; the earth and moon hanging on the sharp point of the wire *c a e*. From the side of each ball a short pointed wire projects horizontally, from which the fluid passes off in a stream when the machine is worked, and thus motion is given to the whole; the sun and earth moving round their common centre of gravity *a*; and the earth and moon round theirs at *b*. The weights of the balls may be so nicely adjusted that E and M will make *twelve* revolutions round *b*, in the time that S and E make *one* round *a*.

3. The *electrical inclined plane*. This is a highly beautiful experiment, and satisfactorily shows that the

electrical matter issuing from a number of points possesses force sufficient to counteract the power of gravity in light bodies. Fig. 9 represents the inclined plane, where A is a board of mahogany, fourteen inches long and four inches broad; B B B B are four glass pillars, three-tenths of an inch in thickness; the length of the two longer is seven inches, and that of the two shorter is five inches.

From the longer to the shorter pillars are stretched two fine brass wires, parallel to each other, and tightened by screws which pass through the brass balls which surmount the pillars. On these wires the axis of the fly C rests, the ends of which are formed like a small pulley, having a groove in them to prevent their slipping off the wires, and to guide the fly when in action. It is obvious that if the fly be placed on the upper part of the wires it will roll down them by its own gravity; but when it has reached the bottom of the plane, if the upper end of the wires be connected with the machine while in action, the escape of the fluid from the points will cause it to roll very rapidly up the plane till it reach the top of it.

These experiments may be varied to a great extent. and models of corn-mills, water-pumps, astronomical clocks, &c., constructed of cork and pasteboard, are readily put in action by directing against their main wheels a stream of electricity from a strong pointed wire inserted into the prime conductor.

Of the Leyden Jar.

The Leyden jar, or phial, is so called from the circumstance of its properties having been first observed at Leyden by M. Van Kleist, dean of the cathedral in Camin. It consists of a glass jar of any convenient size, having the outside and inside coated with tin foil, to within two or three inches of the top, and a brass wire, the upper part of which must terminate in a ball of the same metal, and the lower part in a fine chain, or a piece of fine wire, that it may touch the inside of the jar, passing through a lid of baked wood which fits into the mouth of the jar. This jar, as commonly used, is represented by fig. 10. If a jar thus constructed be held by the lower part with the hand, and the knob be brought in contact with the prime conductor while the machine is in action, it will become charged; and if a communication be then formed between its outside and inside coatings, by the other hand being brought to the knob, that sensation called the electrical shock will be felt, and the jar will thus be discharged. But when it is required to pass the charge of the jar through any particular substance, the jointed discharging rod must be used, Fig. 11, which is mounted on a glass handle, to prevent the dispersion of the fluid. Any number of these jars combined together, and having a communication formed between their exterior and interior coatings, is called an electrical battery. Fig. 1, plate XII. For experiments that do not require great power, two or three jars are sometimes connected together by wires; and this is often more convenient than charging the battery; but where great power is required, the battery is indispensable to success. In using a single jar it is often desirable, and sometimes even necessary, to measure accurately the strength of the charge. This is effected by means of an instrument called the electrometer, the simplest form of which is represented by fig. 13, plate XI. and consists of an upright stem of box, furnished at the lower end with a brass ferule and pin, by which it may be inserted in the conductor. To the upper part of the stem is affixed a graduated semicircle of ivory, about the middle of which is a brass arm, to support the axis of the index. The index is a very slender stick, which reaches from the centre of the plate to the ferule at the lower end of the stem; and to its extremity is fixed a delicate pith ball. This index rises as the charge proceeds, and when it is completed, will stand at ninety, or at right angles with the stem.

The *universal discharger* is another instrument that will be found necessary in a great variety of experiments in which the battery is to be used.

Fig. 14 is a representation of Henley's universal discharger. A is a flat board, about fifteen inches long, four broad, and one thick. BB are two glass pillars, cemented in two holes upon the board A, and furnished at top with brass caps, each of which has a turning joint, and supports a spring tube, through which the wires D D slide. Each of the caps is composed of three pieces of brass, connected so that the wires D D, besides their sliding through the sockets, have a horizontal and vertical motion. Each of the wires D D is furnished with an open ring at one end, and at the other it has a brass ball, which, by a short spring socket, is slipped upon the pointed extremity, and may be removed. E is a circular piece of wood, having on its surface a slip of ivory inlaid, and furnished with a foot, which is fastened in the middle of the bottom A.

To this discharger belongs the small press, Fig. 15, the stem of which fits into the socket, instead of the circular table E. On the top of the stem are two oblong boards, which are pressed together by means of two screws. Between these boards may be placed any substance which requires to be pressed while the electric fluid is sent through it.

The construction of this instrument is such as to enable the operator to use it with advantage in numerous experiments, such as the oxidation of metallic leaves between slips of card or of glass; splitting small pieces of oak, firing gunpowder, &c.

By far the most interesting and brilliant application of the powers of the Leyden jar is the melting of metallic wires. When a strong charge is passed through a slender iron wire, the wire is ignited or dispersed in red-hot globules. The power of large batteries was formerly considered essential to the production of this effect; but if the wire be sufficiently fine, a single jar, exposing a coated surface of about 190 square inches, will be found sufficient to exemplify the experiment. The finest flatted steel wire, sold at the watchmakers' tool shops, by the name of watch-pendulum wire, answers exceedingly well.

Cuthbertson's Balance Electrometer is an excellent and elegant regulator of the strength of the charge requisite for fusing different lengths of wire; and in public lectures is an indispensable article of apparatus.

Fig. 16 represents this instrument, with the common quadrant electrometer inserted in the centre of the upper arm, which, it may be sufficient to mention, is accurately poised on a knife-edged centre. In using this electrometer, the arm A must be connected with the inside of the jar, and the insulated ball B with the outside. The wire to be fused must form part of the circuit. When the jar or battery is charged, C will be repelled by A, and D will thus descend to B, and discharge the jar or battery through the wire, which will be fused and run into balls. From numerous experiments, it appears that the action of electricity on wires increases in the ratio of the square of the increased power; since *two* jars, charged to any degree, will melt four times the length of wire that is melted by *one jar;* and this will again be *quadrupled* by *doubling* the height of the charge.

This law Mr. Singer says he has found to obtain in all accurate experiments, with moderate lengths of wire: with a battery exposing forty feet of coated surface, he has frequently melted eighteen feet of iron wire ($\frac{1}{350}$th of an inch diameter) by a single explosion, and the phenomena were remarkably brilliant, a shower of intensely ignited globules being dispersed in all directions.

Inflammable substances kindled by the electric fluid.

If a small quantity of spirit of wine be poured into a silver table-spoon, and rendered a little warm by being held over a clear fire, it may be inflamed by drawing from it a single spark, when the spoon is held by a person standing on the insulating stool, and holding in his other hand a chain connected with the prime conductor. This experiment is sometimes varied, and rendered more striking, in the following manner. Near the prime conductor of the machine, place on the table three wine glasses; connect the first glass with the conductor by a brass chain, which will reach to the bottom of it; and with it let the second and third be connected by a piece of fine brass wire, bent in the form of the letter A. Fill the first and second glasses with water, and into the third pour a little ether; turn the machine, and with a wire and ball draw a spark from the ether, and it will be immediately inflamed.

Gunpowder may be fired by the charge of a jar sent through it, if it be ground fine, and slightly rammed into a quill: there must be a brass wire inserted in each end of the quill; the wires should be thrust so far in, that their extremities may be within the fifth of an inch of each other. If the powder be mixed with clean steel filings, it will be the more readily fired.

If a small quantity of flax, or of cotton wool, be *loosely* tied on one of the knobs of the discharging rod, and a little finely powdered resin dusted on it, and a jar be discharged by bringing the end of the rod, thus prepared, in contact with the knob of the jar, the charge will pass through the flax, or wool, and in so doing will melt and ignite the resin, and set the whole on fire.

Hydrogen gas may be readily inflamed by the electric spark. Fig. 17 is a representation of the electrical cannon chiefly used for this purpose. It is charged with the gas by holding the mouth of it closely over that of a stone or glass bottle in which the gas is generated; a few seconds will be sufficient; it must then be corked up, and the person who is to discharge it, standing on the insulating stool, must touch with his finger, or with a wire and ball, the knob A, and the spark will pass into the interior of the cannon through the glass tube B, and the gas will explode with a loud report, driving out the cork from the mouth of the cannon to a considerable distance.

Luminous exhibition of the electric fluid.

This effect is produced to the greatest advantage by forming different devices with spangles of tin foil on the surfaces of tubes, or plates of glass, and sending a succession of strong sparks along such devices; the spangles should be placed at a short distance from each other, and fixed on with strong gum water.

A mere inspection of the figures will convey an accurate idea of the nature of this kind of electrical apparatus; and it is only necessary to observe, that the brilliancy of these exhibitions will depend on the darkness of the room in which they are made, the dryness of the apparatus, and the strength of the sparks. Fig. 18 is a representation of the simplest instrument used for this purpose; from the form of the direction in which the spangles are stuck on the glass, it is called the spiral tube. When used, it is held in the hand by one end, while the other is brought sufficiently near the prime conductor to receive the spark.

Fig. 19 shows a combination of such tubes called the *illuminated dome,* the effect of which is extremely vivid when the experiment is well managed. Fig. 20 is a device for exhibiting the luminous appearance of the fluid through different colours painted on glass: the effect of this is also remarkably fine.

It is not necessary here to occupy the time of the reader with directions how to perform experiments of this description, since all that is required is to employ a machine of self-sufficient power to keep up a constant and vivid stream of the electrical matter, and to take care that there be a good conducting substance connected with the termination of the device to carry off the fluid to the earth.

The identity of lightning and the electric fluid.

Various proofs of this have been adduced by the best writers on electricity; but instead of enumerating them here, it may be sufficient to observe, that in as far as the limited powers of man have been able to carry experiment on the subject, nothing has yet occurred that can be mentioned as indicating the least difference, except in quantity, between the substance that flows so copiously from a good electrical machine, and that which flashes in the heavens, producing some of the most awfully sublime phenomena in nature. But it is in the power of any person capable of using the common electrical apparatus to satisfy himself on this head by raising in the air a common paper kite having a pointed wire projecting a few inches from its highest part, and communicating with the string by which the kite is raised. In this string there should be a very fine thread of wire intertwined, such as is used by the manufacturers of metallic lace; or if this cannot be obtained, the string may be simply wetted with water. If a kite, thus prepared, be raised in the air during a thunder-storm, or at any other time when there is much electricity present, the fluid will descend copiously along the string, and may be collected in jars, and every kind of experiment performed with it as if it had been collected from a machine.

In making this experiment the string of the kite should be coiled round a rod of glass; and a chain should be suspended from it so as to touch the ground, as the electric matter sometimes flows down in such quantities as might prove dangerous to the operator were it not immediately conveyed to the earth.

The knowledge of the identity of lightning and the electric matter produced by the machine has been turned to great advantage in the production of those inventions by which not only valuable property, but, in many instances, human life also, may be protected from the destructive effects of this powerful agent of nature. Valuable, however, as these inventions are, they are comparatively little attended to. Every building that stands in an exposed situation ought to be furnished with a conducting rod to save it from the effects of lightning; yet conductors on buildings are more curious than common in England; nay, what is still worse, church spires are but seldom provided with them, although they are generally surmounted by gilt ornaments peculiarly adapted to draw the lightning from the clouds Ships that go within the tropical climates ought to be provided with the flexible conductors which are so easily adapted to the masts, and which prove a source of safety in the most violent thunder-storms; and yet it is said that masters of vessels sometimes carry these rods out with them, without being at the trouble of having them erected.

The utility of conductors is demonstrated by the common experiment called the thunder-house. This little article is variously constructed, but the most elegant form given to it, and that which shows the effect most strikingly, is that represented by fig. 21. The upper part of the pyramid consists of three distinct pieces, which are all thrown asunder by falling down when the moveable piece *a* is expelled by the charge passing along the conducting rod.

In treating of the luminous appearance of the electric fluid, we should have noticed the singularly beautiful effect produced by passing it through a highly rarefied medium.

The appearance of the fluid in this case strikingly resembles the *aurora borealis;* from which it has been thought that that phenomenon is caused by the electricity of the atmosphere playing in the higher regions. This theory, however, is not well supported, and some recent facts seem to militate against it. To produce this exhibition, a long glass tube, so mounted that it may be readily exhausted of the internal air, is essentially necessary. For this experiment, and numerous others, which we have not room to describe, we would warmly recommend the compound apparatus which is represented at fig. 22. A is an insulating pillar of glass, which is screwed to the wooden foot B; and on this pillar all the apparatus may be screwed alternately. C D is an exhausted tube of glass, furnished at each end with brass caps; at the end D is a valve properly secured under the brass plate; a brass wire, with a ball, projects from the upper cap; a pointed wire proceeds from the bottom plate; and this tube is called the *luminous conductor.* The flask represented at E is called the *Leyden Vacuum.* It is furnished with a valve under the ball E; to come at which the more readily, the ball may be unscrewed; a wire, with a blunt end, projects to within a little of the bottom of the flask, the latter being coated with tin foil; and a female screw is cemented to the bottom, to screw it on the pillar A.—F is a syringe to exhaust the air occasionally, either from the luminous conductor or the Leyden vacuum. To do this, unscrew the ball of the Leyden vacuum, or the plate of the luminous conductor, and then screw the syringe in the place of either of these pieces, being careful that the bottom of the female screw G bears close against the leather which covers the shoulders *a b* or *c d*; then work the syringe, and in a few minutes the glasses will be sufficiently exhausted. H and I are two Leyden bottles; each of which has a female screw fitted to the bottom, that they may be conveniently screwed on the pillar A; and the bottle H is furnished with a belt by which it may be screwed sidewise to the same. K and L are two small wires, to be screwed occasionally either into the ball E, the knobs *e* or *f*, the cap *c*, or the socket *g* on the top of the pillar; the balls may be unscrewed from these wires, which will then exhibit a blunt point. M is a wooden table, to be screwed occasionally on the glass pillar.

Of the two Electricities.

There are two distinct kinds of electricity, which were originally named by Du Fay, who made the discovery, the *vitreous* and the *resinous*, but are now denominated *positive* and *negative* electricity.

In whatever way electricity is produced, whether by friction, evaporation, heating or cooling, there is always the presence of the two distinct electricities. And it is now well known that *every* substance is an electric, or capable by friction of producing electrical phenomena. Thus, for instance, if we take any of those bodies formerly called non-electrics, and insulate it by a rod of glass or of any other convenient substance commonly termed an electric, and rub it with a piece of silk, or worsted, we shall find it become electrical. It will attract and repel light bodies, and yield sparks to the finger that approaches it: the distinction, therefore, formerly made between electrics and non-electrics is groundless, and calculated to mislead.

On this principle we readily perceive how any body by friction may be made to exhibit either of the two electricities, according to the nature of the rubber. The only exception is the back of a cat, which gives the vitreous or positive electricity with every rubber hitherto tried.

The following is a table of several substances which acquire the vitreous electricity, when we rub them with those which follow them in the list; and the resinous electricity, when rubbed with those that precede them:—

The skin of a cat.
Polished or smooth glass.
Woollen stuff or worsted.
Feathers.
Dry wood.
Paper.
Silk.
Lac.
Roughened glass.

The resulting fluids are necessarily co-existent, the one appearing on the body rubbed, and the other on the rubber; but since the one is most usually evolved on the surface-glass, and the other on that of resins, the first has been called the vitreous, and the second the resinous electricity. These two fluids, corresponding to the positive and negative of Franklin, by their reunion produce a species of reciprocal neutralization, and electrical repose.

This may be most satisfactorily shown by the following simple experiment. Excite a glass tube by friction, and bring it gradually towards the gold-leaf electrometer fig. 24, and the leaves will diverge with positive electricity. The same effect will be produced, but by negative electricity, by exciting a large stick of sealing wax. But let both the glass and the wax be excited at the same time, then, holding them in a perpendicular direction, parallel to, and at a little distance from each other, bring them near the electrometer, and not the slightest sign of electricity will be evinced by it.

To the scientific mind the exhibition of the two electricities must ever form a source of superior gratification in consequence of the indefinite variety of which the illustrative experiments admit; the ease with which most of them may be performed; and the extreme beauty and delicacy of many of them. But on this part of the subject we cannot enlarge; nor have we room to enter on the connexion of electricity with the medical science. Yet we must take this opportunity of stating, that, although there are many foolish, and even incredible things on record, as to the medical virtues of electricity, we have also sufficient proof that in the hands of a skilful operator it may, in numerous cases, be applied with certainty of success.

Let no one, however, attempt to apply this agent in the healing art who is not thoroughly competent to judge of the real nature of the case, and to manage the application with prudence and skill.

The Electrophorus.

The electrophorus is certainly a very remarkable source of electrical accumulation, and is an instrument which, for many light experiments, forms a good substitute for the electrical machine. It is one of the ingenious contrivances of professor Volta, and is constructed in the following manner. Procure two circular plates of metal, or of wood covered with tin foil, and well rounded at the edges; these are the conductors: between them is placed a resinous plate, formed by melting together equal parts of shell-lac, resin, and Venice turpentine, and pouring this mixture, whilst fluid, within a tin hoop of the required size, placed on a marble table, from which the plate may be readily separated when cold. This plate should be half an inch in thickness; it is sometimes made by pouring the mixture on one of the conductors, which is then formed with a rim for that purpose. In the centre of the upper conductor is fixed a glass handle of about ten inches long, for the purpose of lifting it without drawing off its electricity; and when the electric state of the lower conductor is to be examined, the whole apparatus must be placed on an insulating stand. To use the electrophorus, rub the upper surface of the resinous plate with a piece of dry fur, cat's skin is reckoned the best, and it will be excited negatively. Place the upper conductor upon it, and then raise the same by its insulating handle; it will be found to exhibit very faint, if any, electrical signs. Replace the conductor, and whilst it lies on the surface of the excited plate, touch it with a finger or any other uninsulated conductor, and then raise it again by its handle.

It will now be positively electrified, and afford a spark: if it be then replaced on the resinous plate, touched, and again raised, another spark will be procured, and this process may be repeated for a considerable time without any perceptible diminution of effect. Jars may be charged by bringing them in contact with the conductor each time it is lifted, with an instrument of this kind only six inches in diameter. Cavallo charged a jar several times successively, and such was the strength of the charge that it was capable of piercing a card.

This instrument, properly constructed, has been known to retain its electricity so long as three weeks, without requiring fresh excitation.

Fig. 23 represents the most common form of the electrophorus; it is sometimes fitted up with a contrivance for producing an instantaneous light by causing the spark to inflame hydrogen gas.

CHAPTER XI.

GALVANISM.

GALVANISM, sometimes called Voltaism, is the name given to a species of electricity produced by connecting dissimilar metals, by means of an intervening and oxidating fluid. It is termed Galvanism from the circumstance of its having been first observed by Galvani, professor of anatomy at Bologna. This philosopher was fortunate enough to make some observations on the electricity of the muscles of frogs, that to him appeared to depend on a new power in the animal body; and although some of the conclusions which he drew from the discovery are now admitted to be erroneous, yet they led to a train of experiments which have immortalized his name, by connecting it with some of the most brilliant discoveries of modern science.

This grand discovery was made by Galvani in the year 1789, since which time it has employed the attention of several eminent philosophers; but those who have most eminently distinguished themselves on the subject are Valli, Volta, Monro, Fowler, Davy, and Wollaston. Electricity, as produced by friction, has hitherto been but of very limited application in any of the useful arts; but the agency of the Galvanic apparatus has totally changed the face of chemistry, and promises a speedy development of the hitherto mysterious nature of magnetism.

Many curious and interesting facts resulted from the researches of the above-mentioned philosophers, but they are by far too numerous to detail in this place; the most important facts which they establish may be reduced to the following heads:—

First, That the passage of a small quantity of electricity through the nerves of any animal occasions a tremulous motion or contraction of the contiguous muscles, and sometimes an extension of the limbs. This effect takes place both in living animals, and in such as have been recently killed, and even in detached limbs of these last. The effect is shown to the greatest advantage on cold-blooded animals, as frogs and fishes, which retain the power of action after death much longer than others.

Secondly, The same effects that are produced by the passage of electricity, also result from the contact of different metals with the nerves and muscles; and the effects are always most considerable when the metals are most essentially different; thus zinc and gold, or zinc and silver, form a very active combination.

Thirdly, By the same means that muscular motion is excited in these trials, some of the senses are remarkably affected, as appears when the experiment is made on living animals.

The following simple and easily performed experiments will demonstrate these facts:—

Take a live frog, and paste a piece of tin-foil on its back, and place it on a plate of zinc; form a communication by means of a fine clean copper wire between the zinc and the tin-foil, and spasmodic convulsions will be immediately produced.

Or procure a small flounder; place it in a dish upon a slip of zinc, and lay a shilling, or other silver coin, upon its back; then, as in the former case, connect the zinc and silver, and strong muscular contractions will be the result.

The human body, whilst undergoing certain chirurgical operations, or its amputated limbs, have been convulsed by the application of metals. But the living animal body may be rendered sensible of the action of metallic application in a harmless way, and both the senses of taste and sight may be affected by it, but in different degrees according to the various constitutions of individuals.

Let a man lay a piece of zinc upon his tongue, and a piece of some other metal, as silver, under the tongue; on forming the communication between these two metals, either by bringing their outer edges in contact, or by the interposition of some other piece of metal, he will perceive a peculiar sensation, accompanied with a sort of cool and subacid taste. The sensation seems to be more distinct when the metals are of the usual temperature of the tongue. The silver or gold may be applied to any other part of the mouth, to the nostrils, to the ear, or to other sensible parts of the body, while the zinc is applied to the tongue; and on making the communication between the two metals, the taste will be perceived upon the tongue. The effect is more remarkable when the zinc touches the tongue in a small part, and the silver in a great portion of its surface. Instead of the tongue, the two metals may also be placed in contact with the roof of the mouth, as far back as possible; and on completing the communication, the irritation will be perceived.

In order to affect the sense of sight by means of metals, let a man in a dark place put a slip of tin-foil upon the bulb of one of his eyes, and a piece of silver in his mouth. On completing the communication between the silver and the tin-foil, a faint flash of white light will appear. This experiment may be performed in a more convenient manner, by placing a piece of zinc between the upper lip and the gums, as high up as possible, and a silver piece of money upon the tongue; or else by putting a piece of silver high up in one of the nostrils, and a piece of zinc in contact with the upper part of the tongue; for in either case the flash of light will appear whenever the two metals are made to communicate, either by the immediate contact of their edges, or by the interposition of other good conductors.

It has been long asserted, that when porter is drank out of a pewter pot, it has a taste different from what it has when drank out of glass or earthenware.

It has been observed, that pure mercury retains its metallic splendour during a long time; but its amalgam with any other metal is soon tarnished or oxidated.

The Etruscan inscriptions, engraved upon pure lead, are preserved to this day; whereas some medals of lead and tin, of no great antiquity, are much corroded. Works of metal, whose parts are soldered together by the interposition of other metals, soon tarnish about the places where the different metals are joined.

When the copper sheeting of ships is fastened on by means of iron nails, those nails, but particularly the copper, are readily corroded about the place of contact.

It has been customary many years past to sheath the ships of the royal navy, and those of the East India service, with copper. But even vessels thus protected have been found to return home, after a long voyage, with the copper sheathing extremely injured from the action of the salt water. This led the indefatigable Sir H. Davy to turn his attention to the subject, and his experiments have been followed with the most complete success. His discovery consists in the simple process of placing in contact with the copper some strips of *positive* metal, zinc for instance, by which the corrosion and foulness from the action of the sea water are prevented.

Since Galvani's discoveries, the action arising from the combination of three conductors has been examined with great care, and with considerable success, especially by Mr. Volta, who discovered that the slight effect of such a combination may be increased to a prodigious degree by repeating the combination; for instance, if a combination of silver, zinc, and water, produce a certain effect, a second combination of another piece of silver, another piece of zinc, and another quantity of water, added to the first, will increase the effect; the addition of a third combination will increase the effect still more.

The apparatus now in use for Galvanic operations is commonly termed the Voltaic battery. This instrument is variously constructed; the powers of the original construction were found to be extremely limited, and the use of it is now almost entirely abandoned. On this account we shall here do little more than refer the reader to the engravings of some of the earliest methods of fitting up the Galvanic battery. The simplest form of this instrument is that to which Volta gave the name of "*corronne des tasses*."

It consists of a row of wine, or other glasses, containing salt and water, or any saline fluid. Into each of these one end of a metallic ore, consisting of a plate of zinc connected by a wire with a plate of copper, is plunged. These ores are so arranged, that the copper extremity of the first is in the same glass with the zinc extremity of the second, the copper of the second with the zinc of the third, and so on in regular order, as exhibited in fig. 1, plate XIII.

This method, as may be seen by inspection, was extremely incommodious, and could not be constructed on such a scale as to obtain great power. Another method, which approximates much nearer to the power of the modern battery, is represented in fig. 2. This is called the Voltaic or Galvanic pile. It consists of a number of plates of zinc and copper, either round or square, of any size, and of an equal number of pieces of cloth of the same form, but rather smaller. These last are soaked in salt water, or very dilute muriatic acid, until they are thoroughly moistened. The pile is then thus constructed. Place a plate of copper upon the table, then on that place a plate of zinc, and on the zinc one of the moistened discs of cloth; upon this a second series of copper, zinc, and moistened cloth in the same order; proceed thus until a series of fifty or sixty repetitions have been placed one upon the other, and the pile is complete. If now the operator moisten both his hands with the saline liquid, and with a finger of one hand touch the bottom of the pile, and with a finger of the other the top or upper plate, a slight shock will be felt at every repetition of the contact.

The preparation, however, of such a pile is a very troublesome operation; and its action, even at the strongest, will never suffice for any of the more brilliant experiments in the electro-chemical science.

The most approved and the most powerful form of the battery is that represented in fig. 3. This consists of an oblong trough of dried mahogany, into which any convenient number of double plates of copper and zinc, soldered together, are united in regular order. The intervening cells are nearly filled with the acid solution, and the action produced by connecting the two ends of the arrangement together by clean copper wires.

For the purpose of insulation, the connecting wires are generally passed through two small glass tubes of about six inches long, and which are to be held in the hands of the operator: these are seen in the figure. The ends of these wires that enter the trough may be made fast by passing them tightly through a small piece of wood firmly fixed into the extreme cells of the trough. The substance to be operated on should be placed upon a plate of strong glass.

In fig. 4 is represented the method generally used for connecting a number of these troughs together when great intensity of action is required: the connexion is formed by a slip of copper passing from the last cell of one trough into the first of that which is placed next to it.

In fig. 5 is represented another method of fitting up the trough. Here the trough A is made of earthenware, having partitions of the same material, and the metallic plates are attached by screws and nuts to a bar of wood, so that they may be immersed and removed at one operation. The troughs are filled with dilute acid, and by uniting them in regular order, the apparatus may be enlarged to any required extent. On this principle the great apparatus of the Royal Institution is constructed. An important improvement has been suggested in the construction of the Voltaic apparatus by Dr. Wollaston, by which great increase of quantity is obtained without inconvenient augmentation of the size of the plates. This improvement consists in extending the copper plate so as to oppose it to every surface of the zinc, as represented in fig. 6. A is the rod of wood to which the plates are screwed in the usual manner. B B the zinc plates connected as usual with the copper plates C C, which are doubled over the zinc plates, and opposed to them on both sides, any contact of the surfaces being prevented by pieces of cork or wood placed at D D. Dr. Wollaston, with a single pair of plates constructed on this principle, succeeded in fusing and igniting a fine platinum wire. This is allowed to be the most economical and useful form in which the Voltaic apparatus has yet been constructed.

The reader will now perceive that he may construct his apparatus of any size that is best suited to the nature of the experiments which he has occasion to make. With a trough containing ten pairs of four-inch plates, fitted up on the principle last explained, he may safely proceed with the more common experiments; but if he wish great intensity of action, he should never have fewer than from 150 to 200 pairs of such plates in the best possible state of action.

Experience is the best guide with respect to the preparation of the fluid with which the troughs are to be filled; but, in general, from one part of muriatic acid and sixteen parts of water, to one of acid and twenty of water, are found to be the most convenient proportions. The acid and water should be mixed in any large earthenware vessel, and well stirred with a glass rod before the compound is poured into the trough; the cells should be filled to within a quarter of an inch of the top, and the upper edges of the plates wiped perfectly dry with a cloth. It may be necessary to observe that the action is always strongest at the first; in which case the operator should study to apply it in the first instance to those experiments which require the greatest intensity of the Voltaic power.

The most extraordinary phenomena of a Galvanic battery are the chemical effects and the modifications which are produced by it upon the bodies concerned, or upon such as are placed in the circuit. We shall here describe the simplest mode of exhibiting the principal of those phenomena, namely, the evolution of gas from water, from which the mode of conducting similar experiments is easily derived.

A B, fig. 7, exhibits a glass tube full of distilled water, and having a cork at each extremity. E F is a brass or copper wire, which proceeds from one extremity of a Galvanic battery, and passing through the cork A, projects within the tube. H G is a similar wire, which proceeds from the other extremity of the battery, and comes with its extremity G within the distance of about an inch or two from the wire F.

In this situation of things, it will be found that bubbles of gas proceed in a constant stream from the surface G of the wire which proceeds from the negative end of the battery; these bubbles of gas, ascending to the upper part of the tube, accumulate by degrees. This gas is the hydrogen, and may be inflamed. At the same time the other wire F deposits a stream of oxide in the form of a cloud, which accumulates in a greenish form in the water, or on the sides of the tube, and is a perfect oxide of the brass. The wire F is discoloured and corroded. If you interrupt the circuit, the production of gas and of oxide ceases immediately. Complete the circuit, and the production of gas reappears.

When the poles or extremities of the Voltaic battery are connected by a steel wire, it becomes magnetic; and if by a platinum or other metallic wire, that wire exhibits numerous magnetic poles, which attract and repel the common magnetic needle. This was first discovered by Professor Oersted of Copenhagen.

But by far the most important discovery hitherto made by the application of Galvanism was that of decomposing the alkalis.

The honour of this discovery belongs to Sir H. Davy. He found that a thin piece of potash, or soda, slightly moistened by exposure to the air, and placed between two conductors of platinum, proceeding from the opposite poles of the Voltaic battery, was quickly resolved into a metalline substance highly inflammable, which appeared at the negative surface, and oxygen gas, which was evolved at the positive surface. This new metal will be found described under the article CHEMISTRY. For the information of those who may feel desirous of trying this interesting experiment, it may be proper to remark, that a battery of 100 pairs of three or four inch plates will be found sufficient for the purpose. The apparatus should be excited by a weak acid mixture, of about one part of good muriatic acid to thirty parts of water. A plate of silver or platina being connected with the negative side of the battery, a thin piece of pure potash or soda must be placed upon it, and a platina or silver conductor, proceeding from the positive side of the battery, is then to be brought in contact with the upper surface of the alkali, which soon fuses at the points of contact; metallic globules soon appear near the negative surface, and gradually increase in size, until a crust of alkali begins to form on their surface: at this moment they must be removed by the point of a knife, and instantly plunged into naphtha. This experiment requires very great care to insure success, which a trifling variation in the power of the battery, the purity of the potash, or the moisture of the atmosphere, may prevent.

Before quitting this subject, we would introduce some remarks on the effect of this wonderful agent on the animal system. This, we think, cannot be rendered more intensely interesting than by subjoining the following account of some successfully conducted experiments by Dr. Ure of Glasgow, on the body of a man of the name of Clydesdale, who was executed at Glasgow for murder.

The subject of these experiments, says Dr. Ure, was a middle-sized, athletic, and extremely muscular man, about thirty years of age. He was suspended from the gallows nearly an hour, and made no convulsive struggle after he dropped; while a thief, executed along with him, was violently agitated for a considerable time. He was brought to the anatomical theatre of our university in about ten minutes after he was cut down. His face had a perfectly natural aspect, being neither livid nor tumefied; and there was no dislocation of his neck.

Dr. Jeffray, the distinguished professor of anatomy, having on the preceding day requested me to perform the Galvanic experiments, I sent to his theatre, with this view, next morning, my *minor* Voltaic battery, consisting of 270 pairs of four-inch plates, with wires of communication, and pointed metallic rods with insulating handles, for the more commodious application of the electric power. About five minutes before the police officers arrived with the body, the battery was charged with a dilute nitro-sulphuric acid, which speedily brought it into a state of intense action. The dissections were skilfully executed by Mr. Marshall, under the superintendence of the professor.

Exp. 1. A large incision was made into the nape of the neck, close below the *occiput*. The posterior half of the *atlas vertebra* was then removed by bone forceps, when the spinal marrow was brought into view. A profuse flow of liquid blood gushed from the wound, inundating the floor. A considerable incision was at the same time made in the left hip, through the great gluteal muscle, so as to bring the sciatic nerve into sight, and a small cut was made in the heel. From neither of these did any blood flow. The pointed rod, connected with one end of the battery, was now placed in contact with the spinal marrow, while the other rod was applied to the sciatic nerve. Every muscle of the body was immediately agitated with convulsive movements, resembling a violent shuddering from cold. The left side was most powerfully convulsed at each renewal of the electric contact: on moving the second rod from the hip to the heel, the knee being previously bent, the leg was thrown out with such violence as nearly to overturn one of the assistants, who in vain attempted to prevent its extension.

Exp. 2. The left phrenic nerve was now laid bare at the outer edge of the *sternothyroideus* muscle, from three to four inches above the clavicle; the cutaneous incision having been made by the side of the sterno-cleido mastoideus. Since this nerve is distributed to the diaphragm, and since it communicates with the heart through the eighth pair, it was expected, by transmitting the Galvanic power along it, that the respiratory process would be renewed. Accordingly, a small incision having been made under the cartilage of the seventh rib, the point of the one insulating rod was brought into contact with the great head of the diaphragm, while the other point was applied to the phrenic nerve in the neck.

This muscle, the main agent of respiration, was instantly contracted, but with less force than was expected. Satisfied, from ample experience on the living body, that more powerful effects can be produced, in Galvanic excitation, by leaving the extreme communicating rods in close contact with the parts to be operated on, while the electric chain or circuit is completed by running the ends of the wires along the top of the plates in the last trough of either pole, the other wire being steadily immersed in the last cell of the opposite pole, I had immediate recourse to this method. The success of it was truly wonderful. Full, nay, laborious breathing, instantly commenced. The chest heaved and fell; the belly was protruded, and again collapsed, with the relaxing and retiring diaphragm. This process was continued, without interruption, as long as I continued the electric discharges.

In the judgment of many scientific gentlemen who witnessed the scene, this respiratory experiment was perhaps the most striking ever made with a philosophical apparatus. Let it also be remembered, that for full half an hour before this period, the body had been well nigh drained of its blood, and the spinal marrow severely lacerated. No pulsation could be perceived meanwhile at the heart or wrist; but it may be supposed, that but for the evacuation of the blood, —the essential stimulus of that organ,—this phenomenon might also have occurred.

Exp. 3. The supra-orbital nerve was laid bare in the forehead, as it issues through the supra-ciliary *foramen*, in the eyebrow: the one conducting rod being applied to it, and the other to the heel, most extraordinary grimaces were exhibited every time that the electric discharges were made, by running the wire in my hand along the edges of the last trough, from the 220th to the 270th pair of plates: thus fifty shocks, each greater than the preceding one, were given in two seconds. Every muscle in his countenance was simultaneously thrown into fearful action; rage, horror, despair, anguish, and ghastly smiles, united their hideous expression in the murderer's face, surpassing far the wildest representations of a Fuseli or a Kean. At this period several of the spectators were forced to leave the apartment from terror or sickness, and one gentleman fainted.

Exp. 4. The last Galvanic experiment consisted in transmitting the electric power from the spinal marrow to the ulnar nerve, as it passes by the internal condyle at the elbow: the fingers now moved nimbly, like those of a violin performer; an assistant who tried to close the fist found the hand to open forcibly, in spite of his efforts. When the one rod was applied to a slight incision in the tip of the fore-finger, the fist being previously clenched, that finger extended instantly; and from the convulsive agitation of the arm, he seemed to point to the different spectators, some of whom thought he had come to life.

About an hour was spent in these operations.

CHAPTER XII.

MAGNETISM.

The natural magnet, or loadstone, is a hard mineral body of a dark brown, or almost black colour, and when examined, is found to be an ore of iron. It is met with in various countries, generally in iron mines, and of all sizes and forms.

It is not precisely known when and by whom the directive property of the magnet was discovered. The most probable accounts seem to prove that it was known early in the 13th century; and that the person who first made mariners' compasses, at least in Europe, was a Neapolitan of the name of Flavio, or John de Gioga, or Giova, or Gira.

The natural loadstone has also the quality of communicating its properties to iron and steel; and when pieces of steel properly prepared are touched, as it is called, by the loadstone, they are denominated artificial magnets.

These artificial magnets are even capable of being made more powerful than the natural ones; and as they can be made of any form, and are more convenient, they are now universally used, so that the loadstone or natural magnet is only kept as a curiosity.

All magnets, whether natural or artificial, are distinguished from other bodies by the following characteristics.

1. A magnet attracts iron.

2. When a magnet is placed so as to be at liberty to move freely in every direction, its ends point towards the poles of the earth, or very nearly so; and each end always points to the same pole. This is called the polarity of the magnet; the ends of the magnet are called poles; and they are called the north and south poles of the magnet, according as they point to the north or south pole of the earth. When a magnet places itself in this direction, it is said to traverse.

3. When the north pole of one magnet is presented to the south of another magnet, these ends attract each other; but if the south pole of one magnet is presented to the south pole of another, or the north pole of one to the north pole of another, these ends will repel each other.

4. When a magnet is situated so as to be at liberty to move itself with sufficient freedom, its two poles do not lie in a horizontal direction, but it generally inclines one of them towards the horizon, and of course it elevates the other pole above it. This is called the inclination or dipping of the magnet.

5. Any magnets may, by proper methods, be made to impart those properties to iron or steel.

A plane perpendicular to the horizon, and passing through the poles of a magnet when standing in their natural direction, is called the magnetic meridian; and the angle which the magnetic meridian makes with the meridian of the plane where the magnet stands, is called the declination of the magnet at that place.

Magnetic Attraction and Repulsion.

When a piece of iron is brought within a certain distance of one of the poles of a magnet, it is attracted by it; and if the iron is at liberty to move, it adheres to the magnet, and cannot be separated without some force. It appears at first sight, that the attraction lies only in the magnet, but experiment proves this attraction to be mutual, the iron attracting the magnet as much as the magnet attracts the iron. This attraction is strongest at the poles of a magnet, and diminishes in proportion to the distance of any part from the poles, so that in the middle between the poles there is no attraction. The intensity of the attractive power diminishes, also, according to the distance from the magnet.

As magnetic attraction takes place only between poles of different names of different magnets, consequently magnetic repulsion acts only between poles of the same name of different magnets. When a piece of iron is brought within a certain distance of a magnet, it becomes, in fact, itself a magnet, having the polarity, the attractive and repulsive properties for other iron, &c. Thus if A B, plate XIII. fig. 8, be an oblong piece of iron, and be brought near the north pole N of the magnet N S, this piece of iron, while standing within the magnet's sphere of action, will have all the properties of a real magnet, and its end A will be found to be a south pole, while the end B is a north pole. Soft iron, when placed within the influence of a magnet, easily acquires these properties; but they last only while the iron remains in that situation, and when it is removed its magnetism vanishes immediately. But with iron containing carbon, and particularly with steel, the case is very different; and the harder the iron or the steel is, the more permanent is the magnetism which it acquires from the influence of a magnet; but it will be in the same proportion more difficult to render it magnetic. Neither the magnetic attraction nor repulsion is in the least diminished, or at all affected, by the interposition of any sort of bodies, except iron, or such bodies as contain iron.

The properties of the magnet are not affected either by the presence or by the absence of air. Heat weakens the power of a magnet, and subsequent cooling restores it, but not quite to its former degree. A white heat destroys it entirely, or very nearly so; and hence it appears, that the powers of magnets must be varying continually.

The attractive power of a magnet may be considerably improved by suspending a weight of iron to it by its power of attraction, which may be gradually increased; and also by keeping it in a proper situation, viz. with its north pole towards the north, and its south pole, consequently, towards the south. On the contrary, this power is diminished by an improper situation, and by keeping too small a piece of iron, or no iron at all, appended to it.

Amongst the natural magnets, the smallest generally possess a greater attractive power in proportion to their size than those of a larger size. It frequently happens that a natural magnet, cut off from a larger loadstone, will be able to lift a greater weight of iron than the original loadstone itself. As both magnetic poles together attract a much greater weight than a single pole; and as the two poles of a magnet generally are in opposite parts of its surface, in which case it is almost impossible to adapt the same piece of iron to them both at the same time; therefore it has been commonly practised to adapt two broad pieces of soft iron to the poles of the stone, and to let them project on one side of the stone; for those pieces become themselves magnetic while thus situated, and to them the piece of iron or weight may be easily adapted. Those two pieces of iron are generally fastened upon the stone by means of a brass or silver box. The magnet in this case is said to be armed; and the two pieces of iron are called the armature.

Fig. 9 represents an armed magnet, where A B is the loadstone; C D, C D, are the armature, or the two pieces of soft iron, to the projections of which D D the iron weight F is to be applied. The dots E C D C D represent the brass box, with a ring at E, by which the armed magnet may be suspended.

Of the Polarity of the Magnet.

Every magnet has a south and north pole, which are at opposite ends; and a line drawn from one end to the other passes through the centre of the magnet. Here it must not be understood, that the polarity of a magnet resides only in two points of its surface; for, in reality, it is the one half of the magnet that is possessed of one kind of polarity, and the other half of the other kind of polarity; the poles, then, are those points in which that power is the strongest.

It is the polarity of the magnet that renders it so useful to navigators. When a magnet is kept suspended freely, so that it may turn north and south, the pilot, by looking at the position of it, can steer his course in any required direction. Although the north pole of the magnet in every part of the world, when suspended, points towards the northern parts, and the south pole towards the southern parts, yet its ends seldom point exactly towards the poles of the earth.

The angle in which it deviates from due north and south is called the angle of declination, or the declination of the magnetic needle, or the variation of the compass; and this declination is said to be east or west, according as the north pole of the needle is eastward or westward of the astronomical meridian of the place. This deviation from the meridian is not the same in all parts of the world, but is different in different places, and it is even continually varying in the same place.

The declination from the meridian, and the variation of this in different parts of the world, are very uncertain, and have hitherto formed a great impediment to the improvement of navigation. This however is likely to be in a great measure removed, by the successful experiments of Mr. Barlow, on the local attraction of vessels. When the variation was first observed, the north pole of the magnetic needle declined eastward of the meridian of London; but it has since that time been changing continually towards the west; so that in the year 1657 the magnetic needle pointed due north and south. At present it declines about 24½° westward, but seems to be returning again towards the east. Before volcanic eruptions and earthquakes, the magnetic needle is often subject to very extraordinary movements. It is also agitated before and after the appearance of the aurora borealis; a circumstance which indicates a near affinity between electricity and magnetism.

Inclination or Dip of the Magnetic Needle.

If a needle which is accurately balanced, and suspended so as to turn freely in a vertical plane, is rendered magnetical, the north pole will be depressed, and the south pole elevated above the horizon; this property is called the inclination, or dip of the needle, and was discovered by Robert Norman about the year 1576.

Take a globular magnet, or an oblong one, like S N, fig. 1, plate XIV.; the extremity N of which is the north pole, the other extremity S is the south pole, and A is its middle or equator; place it horizontally upon a table CD: then take another small oblong magnet *n s*, and suspend it by means of a fine thread tied to its middle, so as to remain in a horizontal position, when not disturbed by the vicinity of iron. Now if the same small magnet, held by the upper part of the thread, be brought just over the middle of the large magnet, within two or three inches of it, the former will turn its south pole *s* towards the north pole N of the large magnet, and its north pole *n* towards the south pole S of the large one. It will be farther observed, that the small magnet, whilst kept just over the middle A of the large one, will remain parallel to it; but if the small magnet be moved a little nearer to one end than to the other of the large magnet, then one of its poles, namely, that which is nearest to the contrary pole of the large magnet, will be inclined downwards, and of course the other pole will be elevated above the horizon. If the small magnet be brought just opposite to one of the poles of the large magnet, it will turn the contrary pole towards it, and will place itself in the same straight line with the axis of the large magnet.

To communicate the magnetic virtue

There are various methods of giving the magnetic property to steel or iron. Take a bar of iron three or four feet long, and hold it in a vertical position, you will find that the bar is magnetic. If the bar be inverted, the polarity will be instantly reversed; the extremity which is now lowest will be found to be a north pole, and the other extremity will be a south pole.

Bars of iron that have stood in a perpendicular position are generally found to be magnetical, as fire-irons, bars of windows, &c. If a long piece of hard iron is made red-hot, and then left to cool in the direction of the magnetical line, it becomes magnetical. Striking an iron bar with a hammer, or rubbing it with a file, while held in this direction, likewise renders it magnetical. An electric shock produces the same effect; and lightning often renders iron magnetic. A magnet cannot communicate a degree of magnetism stronger than that which itself possesses; but two or more magnets, joined together, may communicate a greater power to a piece of steel than either of them possesses singly.

1. Place two magnetic bars, A, B, fig. 2, in a line, with the north end of one opposed to the south end of the other, but at such a distance from each other, that the magnet to be touched may rest with its north end on the south end of A, and *vice versa*, then apply the north end of the magnet E, and the south end of D, to the middle of the bar C, the opposite ends being elevated as in the figure; draw E and D asunder along the bar C, one towards A, the other towards B, preserving the same elevation; remove E and D a foot or two from the bar when they are off the ends, then bring the north and south poles of these magnets together, and apply them again to the middle of the bar C as before: repeat the same process five or six times, then turn the bar and touch the opposite surface in the same manner, and afterwards the two remaining surfaces; by this means the bar will acquire a strong fixed magnetism.

2. Place the two bars which are to be touched parallel to each other; and then unite the ends by two pieces of soft iron, called supporters, in order to preserve, during the operation, the circulation of the magnetic matter; the bars are to be placed so that the end D, fig. 3, may be opposite the end B; then place the two attracting poles G and I on the middle of one of the bars to be touched, raising the ends, so that the bars may form an obtuse angle of 100 or 120 degrees; the ends G and I of the bars are to be separated two or three tenths of an inch from each other. Keeping the bars in this position, move them slowly over the bar AB, from one end to the other, going from end to end about fifteen times. Having done this, change the poles of the bars, and repeat the same operation on the bar CD, and then on the opposite faces of the bars. The touch thus communicated may

be further increased by rubbing the different faces of the bars with sets of magnetic bars, disposed as in fig. 4.

It may, perhaps, be necessary to say something concerning the communication of magnetism to crooked bars like ABC, fig. 5. Place the bar flat upon a table, and to its extremities apply the magnetic bars DF, EG; joining their extremities FG with the conductor or piece of soft iron FG; then to its middle apply the magnetic bars placed at an angle: or you may use two bars only, placed as shown in fig. 2, and stroke the crooked bar with them from end to end, following the direction of that bent bar, so that on one side of it the bars may stand in the direction of the dotted representation LK. In this manner, when the piece of steel ABC has been rubbed a sufficient number of times on one side, it must be turned with the other side upwards, &c.

The magnetic needles which are commonly used at sea are between four and six inches long; but those which are used for observing the daily variation are made a little longer, and their extremities point the variation upon an arch or circle, properly divided, and affixed to the box. The best shape of a magnetic needle is represented in figs. 6 and 7; the first of which shows the upper side, and the second shows a lateral view of the needle, which is of steel, having a pretty large hole in the middle, to which a conical piece of agate is adapted, by means of a brass piece O, into which the agate-cap is fastened. Then the apex of this hollow cap rests upon the point of a pin F, which is fixed in the centre of the box, and upon which the needle, being properly balanced, turns freely.

A mariner's compass, or compass generally used on board of ships, is represented in fig. 8. The box, which contains the card or fly with the needle, is made of a circular form, and either of wood, or brass, or copper. It is suspended within the box by means of two concentric circles, called gimbalds, so fixed by cross axes to the two boxes, that the inner one, or compass-box, shall retain a horizontal position in all motions of the ship. The compass-box is covered with a pane of glass, in order that the motion of the card may not be disturbed by the wind. What is called the card is a circular piece of paper, which is fastened upon the needle, and moves with it. The outer edge of this card is divided into 360 equal parts or degrees, and within the circle of those divisions it is again divided into 32 equal parts, which are called the points of the compass, or rhumbs, each of which is often subdivided into quarters. The initial letters N, NE, &c. are annexed to those rhumbs, to denote the north, north-east, &c.

The azimuth compass is nothing more than the above-mentioned compass, to which two sights are adapted, through which the sun is to be seen, in order to find its azimuth, and from thence to ascertain the declination of the magnetic needle.

ELECTRO-MAGNETISM.

Among the numerous and important discoveries of the present age deserves to be ranked the subject of Electro-Magnetism, a name given to a class of phenomena first observed by M. Oersted, of Copenhagen, in 1819-20, and since then very fully illustrated by M. Ampere, M. Arago, Sir H. Davy, Dr. Wollaston, Mr. Farady, Mr. De la Rive, but more fully still by Mr. Peter Barlow, of the Royal Military Academy, who has published a course of experiments in the science, and described the theory of it, in his excellent Essay on Magnetic Attractions, second edition.

On this subject our limits will only permit us to give the following outline; but the student who is desirous of more minute information may profitably consult Mr. Barlow's Essay, and also the Supplement to Mr. Partington's Introduction to Electricity.

Let the opposite poles of a voltaic battery be connected by a metallic wire, which may be left of such length as to suffer its being bent or turned in various directions. This is the conjunctive wire of M. Oersted. Let us suppose that the rectilinear portion of this wire is extended horizontally in the line of the magnetic meridian. If a freely suspended compass needle be now introduced, with its centre *under* the conjunctive wire, the needle will instantly deviate from the magnetic meridian; and it will decline towards the *west*, under that part of the conjunctive wire which is nearest the negative electric pole, or the copper end of the voltaic apparatus. The amount of this declination depends on the strength of the electricity, and the sensibility of the needle.

Its *maximum* is 90°. We may change the direction of the conjunctive wire, out of the magnetic meridian, towards the east or the west, provided it remains above the needle, and parallel to its plane, without any change in the above result, except that of its amount. Wires of platinum, gold, silver, brass, and iron, may be equally employed; nor does the effect cease though the electric circuit be partially formed by water. The effect of the conjunctive wire takes place across plates of glass, metal, wood, water, resin, pottery, and stone. If the conjunctive wire be disposed horizontally *beneath* the needle, the effects are of the same nature as those which occur when it is *above* it; but they operate in an inverse direction; that is to say, the pole of the needle, under which is placed the portion of the conjunctive wire which receives the negative electricity of the apparatus, declines in that case towards the *east.*

To remember these results more readily, we may employ the following proposition: *The pole* ABOVE, *which the negative electricity enters, declines towards the* WEST; *but if it enters* BENEATH *it, the needle declines towards the* EAST.

If the conjunctive wire (always supposed horizontal) is slowly turned about, so as to form a gradually increasing angle with the magnetic meridian, the declination of the needle increases, if the movement of the wire be towards the line of position of the disturbed needle; it diminishes, on the contrary, if it recede from its position. When the conjunctive wire is stretched along-side of the needle in the same horizontal plane, it occasions no declination either to the east or west; but it causes it merely to incline in a vertical line, so that the pole adjoining the negative influence of the pile on the wire dips when the wire is on its west side, and rises when it is on the east. If we stretch the conjunctive wire, either above or beneath the needle, in a plane perpendicular to the magnetic meridian, it remains at rest, unless the wire be very near the pole of the needle; for, in this case, it rises when the entrance takes place by the west part of the wire, and sinks when it takes place by the east part. When we dispose the conjunctive wire in a vertical line opposite the pole of the needle, and make the upper extremity of the wire receive the electricity of the negative end of the battery, the pole of the needle moves towards the *east*; but if we place the wire opposite a point betwixt the pole and the middle of the needle, it moves to the *west*. The phenomena are presented in an inverse order, when the upper extremity of the conjunctive wire receives the electricity of the positive side of the apparatus.

. It appears from the preceding facts, says M. Oersted, that the electric conflict (action) is not enclosed within the conducting wire, but that it has a pretty extensive sphere of activity round it. We may also conclude from the observations, that this conflict acts by revolution; for without this supposition we could not comprehend how the same portion of the conjunctive wire, which, placed *beneath* the magnetic pole, carries the needle towards the east, when it is placed *above* this pole, should carry it towards the west. But such is the nature of the circular action, that the movements which it produces take place in directions precisely contrary to the two extremities of the same diameter. It appears also, that the circular movement, combined with a progressive movement in the direction of the length of the conjunctive wire, ought to form a kind of action which operates *spirally* around this wire as an axis.

The magnetic property may be communicated to a steel needle, or to several needles at once, by the following simple process. Let the conducting wire have one part of it bent into a spiral form, by twisting twenty or thirty times round a ruler of about an inch in diameter, and let the needle be placed either naked in the spiral, or enclosed in a glass tube, or in a tube of any other matter; complete the connexion between the ends of the battery, and in an instant it will be found that the needle has become strongly magnetic, having its north pole towards the zinc extremity of the battery. The same effect may be produced by the discharge of an electrical battery.

A very remarkable fuct is mentioned by M. Arago respecting the residence of the magnetic virtue in other metals besides iron. He found that a magnetic needle is stopped in its motion by a plate of copper, or any other metal, at rest, although such plate be quite free from particles of iron. He hence inferrred, that a needle at rest would be moved by a plate of any such metal in motion. By experiment, he accordingly found, that if a plate of copper be made to turn with any determinate velocity under a magnetic needle, in a vessel perfectly closed, so as to exclude the motion produced in the external air by the rotation of the plate, the needle will no longer assume its usual position; it stops without the magnetic meridian, and so much the farther from that direction as the revolution of the plate is more rapid. If the velocity of the plate be sufficient, the needle itself, at a considerable distance from the plate, will turn continually round the wire on which it is suspended.

These experiments have been repeated, extended, and minutely examined by Mr. Herschel, the son of the late astronomer of that name, in conjunction with Mr. Babbage, the inventor of the calculating machine. Having erected an apparatus for the purpose, they succeeded, after a few trials, in causing a compass to deviate from the magnetic meridian, by setting in rotation under it plates of copper, zinc, lead, &c. To obtain more visible and regular effects, however, they found it necessary to reverse the experiment, by setting in rotation a powerful horse-shoe magnet, and suspending over it the various metals, and other substances to be examined, which were found to follow the magnet with various degrees of readiness. The substances in which they succeeded in developing signs of magnetism were copper, zinc, silver, tin, lead, antimony, quicksilver, gold, bismuth, and carbon in that peculiar state resembling a metal in which it is precipitated from carburetted hydrogen in gas-works. In other bodies, such as sulphuric acid, resin, glass, and other non-conductors or imperfect conductors of *electricity,* no positive evidence of magnetism was obtained. The metals, it will be recollected, are *conductors* of electricity.

Messrs. Herschel and Babbage then determined in numbers the comparative intensities of action of these bodies, or the comparative capability they possess of imparting rotation to a magnetic needle and receiving it from a magnet. The results were as follows:—Copper 100, zinc 93, tin 46, lead 25, antimony 9, bismuth 2. Of the other metals, silver appears to hold a high rank, and gold a very low one, in the scale of magnetic energy.

They next investigated the effect of division of the metallic plates employed; when they verified the result already obtained by M. Arago, that cutting slits in them diminishes their intensity of action; and further ascertained the curious fact, that re-establishing the metallic contact with other metals, or in other words soldering up the slits, restores the force, either wholly or in great measure; and that, even when the metal used for soldering has in itself but a very feeble magnetic power. The law of diminution of the magnetic force developed by rotation, by increase of distance, was also examined. It appears to follow no constant progression according to a fixed power of the distance, but to vary between the square and the cube.

The experimenters conceive that all these facts may be explained without any new hypothesis, by supposing simply that time is requisite both for the development and loss of magnetism; and that different metals differ, in respect not only of the time they require, but in the intensity of the magnetic force ultimately producible in them. Messrs. Herschel and Babbage's experiments are detailed in the Philosophical Transactions for 1825.

From some experiments on the *Effects of Cold and Heat on the Magnetic Power,* made by Messrs. Christie and Faraday, it appears that the intensity or attractive power of a magnet is increased by the application of cold, and goes on increasing to the lowest temperature to which it can be exposed. Conversely, of course, its attractive power is diminished by the application of heat, and beyond the temperature of 100 degrees of Fahrenheit's thermometer, which is that commonly used in this country, or in other words just above blood-heat, a portion of the power of the magnet is permanently destroyed. On a change of temperature, whether of elevation or depression, the most considerable portion of the effect on the intensity of the magnet is produced instantaneously; showing that the magnetic power resides on or very near the surface. The effects produced on unpolarized iron (or in more common though less accurate language, *unmagnetized* iron, since all iron possesses the attractive power, though in its ordinary state it is destitute of *polarity*, or the power, when freely suspended, of pointing north and south), by changes of temperature, are directly the reverse of those produced on a magnet; an increase of temperature causing an increase in the magnetic power of the iron.

As the variation which daily takes place both in the direction of the magnetic needle and in the magnetic intensity of the earth appears to have a reference to the position of the sun with regard to the magnetic meridian, it is therefore probable, Mr. Christie infers, that the sun is the principal cause of both these phænomena. And the circumstance of the situation of the magnetic poles, or those points of the earth to which the needle is directed (which do not coincide with the extremities of the earth's axis usually called the *poles*, though they are adjacent to them), in what appear to be independent of elevation in the atmosphere, the coldest regions of the globe, supported as it is, by the fact above mentioned, of a diminution of temperature causing an increase of magnetic intensity, would lead us to infer (he adds) that the effect produced by the sun is principally to be attributed to the heat developed by its rays.

Before quitting this article, we shall briefly notice

Mr. Barlow's admirable discovery of a method of counteracting the local attraction of vessels. For this discovery, Mr. Barlow received the highest reward, viz. that of £500, given by the Board of Longitude. The instrument, as constructed by Mr. Barlow, is thus described. The centre of a small circular plate of iron is placed in the line of the attraction of the ship's iron, and at a proper distance behind and below the pivot of the compass-needle; the position of this line having been previously ascertained, an operation now rendered easy by the tables for this purpose prepared by Mr. Barlow, and given with the instrument. When this is done, the needle will remain active and vigorous in the polar regions, and will direct itself in the true magnetic meridian, in whatever part of the world the ship may be. This effect of Mr. Barlow's invention has been established by experiments, between the 61° of south latitude, and the 81° of north latitude, by the accurate observations of Lieutenant Foster, and other naval officers.

With respect to the plate itself, it has hitherto been made double, viz. of two plates screwed together, in such a manner as to combine any strong irregular power of the one with a like weak point in the other; by which means a more uniform attraction is obtained. The plates may vary from 12 to 16 inches in diameter, according to the power of the vessel. They have a hole in their centre, through which is passed a brass socket, with a broad head, and with an exterior screw or nut, by which the two plates and an interposed piece of wood of the same size are compressed strongly together, the board being intended to increase the thickness, without adding much to the weight; and it is found that the two plates thus separated are more powerful than when in contact. Fig. 9. shows the whole combined as in action on ship-board.

CHAPTER XIII.

CHEMISTRY.

This branch of science teaches us how to investigate the composition of material substances, and the permanent changes of constitution which their mutual actions produce.

In no science does modern improvement appear so conspicuous; and in none can it boast of so extensive utility as in chemistry. Such, indeed, is the present state of chemical science, that it might be pronounced perfect, were it not that the progress which it is making at the present hour seems to point out the absurdity of attempting to circumscribe it within any limits whatever.

Writers on this subject vary from each other considerably with regard to the order in which they treat its different parts. In the earlier works on chemistry, the operative part usually precedes the theoretical. Some writers treat of compound bodies, and deduce their component parts in the way of analysis; while others begin with the habitudes or powers by which the several changes are effected. But it must be acknowledged that every one of the phenomena of chemistry is, notwithstanding the brilliant discoveries already made, still sufficiently complicated to render it referable to various topics of consideration; so that, generally speaking, it is a matter of little moment to which of these our attention is first directed. Without, therefore, deciding as to the respective merits of these different methods of procedure, we shall, in the following brief outline, adopt that which to us appears the most natural, commencing with the *simple substances.*

By simple substances, in a chemical sense, are to be understood, those bodies which have not hitherto been decompounded. Many substances denominated simple by the old chemists have been, by the moderns, clearly ascertained to be compounds; such, for instance, is atmospheric air; and such also is water. Several substances also, which, but a few years ago, were considered as simple, have been decomposed by Sir H. Davy, and their component parts satisfactorily exhibited to the senses; of this description are the alkalis and earths.

OF THE SIMPLE SUBSTANCES.

These may be said to be, 1. Simple supporters of combustion. 2. Simple combustibles. 3. Simple incombustibles. 4. Metals.

Simple Supporters of Combustion.

1. Oxygen. This substance is so named from two Greek words which signify the production of acid, as one of its properties is the formation of acids by combining with different substances, termed the bases of the acids. Oxygen is one of the most important agents in nature; there is hardly any process, natural or artificial, in which it has not a share. The principal sources whence it is obtained are air and water: in air it is combined with nearly one-third of its weight of hydrogen; in water it is united with azotic, or nitrogen gas, and forms about one-fifth of the atmosphere, the other four-fifths are nitrogen.

It is, however, obtained in the greatest abundance by submitting the black oxide of manganese to a red heat in an iron retort: almost all the metallic oxides will give out oxygen; but when it is wanted in a state of great purity it should be obtained from oxymuriate of potash.

Oxygen gas possesses the mechanical properties of common air: it is termed a supporter of combustion, because, although not inflammable itself, it is the most powerful supporter of combustion.

2. Chlorine. This substance was first discovered by Scheele, who called it *dephlogisticated muriatic acid.*

Like oxygen, it has an affinity for a great number of bodies, and uniting with them, forms compounds of a peculiar nature: it has been found by the experiments of Sir H. Davy to be destitute of oxygen, and yet it is, in some respects, a more powerful supporter of combustion than oxygen itself. Chlorine is obtained by distilling a mixture of black oxide of manganese with muriatic acid. When this mixture is heated, a green-coloured gas rises from it, which may be collected in the common way over water. Several substances, as phosphorus, antimony, &c. take fire of their own accord when plunged into this gas. The term chlorine was assigned to it by Sir H. Davy as descriptive of its colour.

Simple Combustibles.

1. Hydrogen, which, like oxygen, is a gas, and was first called inflammable air: its discovery belongs to Mr. Cavendish. It is the lightest of all gaseous bodies; is colourless, invisible, and possesses the mechanical properties of air. Hydrogen may be obtained by putting some clean iron filings or small chippings into a glass retort, and pouring over them sulphuric acid diluted with thrice its bulk of water. A violent effervescence instantly takes place; gas issues in abundance from the beak of the retort, which may be received over water. This gas, although combustible when in contact with atmospheric air, extinguishes a taper, or even lighted phosphorus, when immersed in it. Its specific gravity is 0.0694; and from its great levity it is used for inflating balloons.

2. Carbon, in its purest form, is known only in the *diamond;* but it may be procured in a state of *charcoal* by burning a piece of wood covered with sand, in a crucible. Charcoal, the combination with which we are the most familiar, is the coaly residuum of any vegetable that has been burned in close vessels. It is generally black, sonorous, brittle, very light, and destitute of taste or smell. Charcoal is a powerful antiseptic, has great affinity for oxygen, is unalterable and indestructible by age, and, if air and moisture be excluded, is not affected by the most intense heat.

3. Phosphorus. This substance is obtained by pouring acetate of lead into urine, and distilling the white powder which precipitates, with some charcoal, in an earthen retort, by means of a strong heat. The beak

of the retort must be inserted in water; the phosphorus will drop into the water like melted wax. Phosphorus, when pure, is semi-transparent; of a yellowish colour: it is soft, and may be cut with a knife. It melts at the temperature of 99°. When exposed to the air it emits a white smoke, which in the dark is luminous. It must be kept in phials of water, closely corked up. The compounds which phosphorus forms with other substances are denominated *phosphorets.*

4. Sulphur. This is one of those combustible substances which have the greatest tendency to combination. It is a hard brittle substance of a yellow colour, and with little taste. It is a non-conductor of electricity, and becomes electric *negatively* by friction. At the heat of 170° it rises up in the form of a fine white powder, well known by the name of flowers of sulphur.

5. Boracium. This substance was discovered by Sir H. Davy. To procure it, equal parts of the metal called potassium and dry boracic acid must, for a few minutes, be exposed in a copper tube to a slight red heat. When cold, the mass must be washed out with water, and the potash saturated with muriatic acid, and the whole filtered. The matter which remains must be washed and dried, and this is *boracium.* It is of a dark olive colour, opaque and brittle, and has some resemblance to charcoal.

Simple Incombustibles.

The only substance under this head with which we are at present acquainted is *azote,* which is also called *nitrogen.* This gas is invisible; possesses the mechanical properties of air; it neither supports flame nor animal life; and although incombustible, it is capable of being combined with oxygen gas. It enters into combination with but few substances.

METALS.

Metals are distinguished by their peculiar lustre, called the metallic lustre: they are opaque, except gold, even in the thinnest plates to which they can be reduced. All the old metals are heavier than water; but some of the new metals discovered by Sir H. Davy are lighter than water. They are the best conductors of electricity known; they are all soft, although some of them have a capacity for great hardness, which may be artificially produced, as may also their elasticity. Some of them are *malleable*, while others are extremely *brittle*; some are *ductile*, and may be drawn into very fine wires; others are destitute of this property. Several of them take fire when heated, and burn with great splendour; and almost all of them may be burnt by peculiar contrivances.

The following are the principal metals now known.

Of Gold.

Gold is always found in nature in a metallic state. It is generally met with in grains, called gold dust, mixed with the sand of rivers; being carried away by them from the rocks and mountains, where it is found in leaves or ramifications, adhering to quartz and other stones.

It is of a rich yellow colour; and is the heaviest of metals, except platina. It is not very hard when pure. It is the most ductile of all the metals. It cannot be oxidated by any heat of a furnace, but may by electricity and galvanism.

Gold is not acted upon by any acid, except the oxygenated muriatic, or nitro-muriatic acids, which latter was called from this aqua regia, because gold was named by the alchymists the king of the metals. With silver it forms an alloy of considerable ductility. Copper heightens its colour, and renders it harder. Tin and lead considerably impair its tenacity. With platina it forms an alloy which is very ductile. With zinc it affords a brittle and hard mixture, susceptible of polish. It unites well with iron, and hardens it remarkably.

On account of its peculiar property of not tarnishing in the air, it is much used for defending other metals; and on account of its beautiful lustre, it is much employed in ornaments. Its specific gravity is 19.3.

Of Platina.

Pure or refined platina is by much the heaviest body in nature. Its sp. gr. is 21.5. It is very malleable, though considerably harder than either gold or silver; and it hardens much under the hammer. Its colour on the touchstone is not distinguishable from that of silver. Pure platina requires a very strong heat to melt it; but when urged by a white heat, its parts will adhere together by hammering. This property, which is distinguished by the name of welding, is peculiar to platina and iron, which resemble each other, likewise, in their infusibility.

Platina is not altered by exposure to air; neither is it acted upon by the most concentrated simple acids, even when boiling, or distilled from it. Its ore has recently been found to contain, likewise, four new metals, palladium, iridium, osmium, and rhodium,—which see; beside iron and chrome.

Of Silver.

Silver is the whitest of all metals, considerably harder than gold, very ductile and malleable, but less malleable than gold; for the continuity of its parts begins to break when it is hammered out into leaves of about the hundred and sixty thousandth of an inch thick, which is more than one third thicker than gold leaf; in this state it does not transmit the light. Its specific gravity is from 10.4 to 10.5. It ignites before melting, and requires a strong heat to fuse it. The heat of common furnaces is insufficient to oxidize it; but the heat of the most powerful burning lenses vitrifies a portion of it, and causes it to emit fumes; which, when received on a plate of gold, are found to be silver in the metallic state. It has likewise been partly oxidized by twenty successive exposures to the heat of the porcelain furnace at Sevres. By passing a strong electric shock through a silver wire, it may be converted into a black oxide; and by a powerful galvanic battery, silver leaf may be made to burn with a beautiful green light. Lavoisier oxidized it by the blowpipe and oxygen gas; and a fine silver wire burns in the kindled united stream of oxygen and hydrogen gases. The air alters it very little, though it is disposed to obtain a thin purple or black coating from the sulphurous vapours which are emitted from animal substances, drains, or putrefying matters. This coating, after a long series of years, has been observed to scale off from images of silver exposed in churches; and was found, on examination, to consist of silver united with sulphur.

Of Mercury.

Mercury, called also quicksilver, always appears in a liquid state, in the common temperature of the atmosphere; but in intense cold, as at 40° below zero, it becomes solid, and is then malleable, resembling silver. It is found in nature, sometimes in a pure state, but chiefly united to sulphur, when it forms cinnabar; and sometimes to silver. It is also united to the acids, and to oxygen. It is mostly found in Spain and South America. Like other fluids, it boils, and is converted into vapour. This process is employed to separate it from other substances. It is acted upon by most of the acids. It combines with sulphur and phosphorus; and forms alloys with most of the metals, which are then called amalgams.

On this property depend some of the methods of gilding and of silvering mirrors. When acted upon by heat and air for a long time, it absorbs oxygen, and is converted into a real oxide, called precipitate per se, or red oxide of mercury. When the heat is increased, this oxide gives out its oxygen, the mercury re-assuming its metallic appearance. When agitated long in air, mercury is converted into a black oxide.

Of Palladium.

This is a new metal, first found by Dr. Wollaston associated with platina, among the grains of which he supposes its ore to exist, or an alloy of it with iridium and osmium, scarcely distinguishable from the crude platina, though it is harder and heavier.

If crude platina be dissolved in nitro-muriatic acid, and precipitated with a solution of muriate of ammonia in hot water; the precipitate washed, and the water added to the remaining solution, and a piece of clean zinc be immersed in this liquid, till no farther action on it takes place; the precipitate now thrown down will be a black powder, commonly consisting of platina, palladium, iridium, rhodium, copper, and lead. The lead and copper may be separated by dilute nitric acid. The remainder being then digested in nitro-muriatic acid, and common salt about half the weight of the precipitate added on the solution, on evaporating this to dryness by a gentle heat, the result will be triple salts of muriate of soda with platina, palladium, and rhodium. Alcohol will dissolve the first and second of these; and the small portion of platina may be precipitated by sal ammoniac. The solution being diluted, and prussiate of potash added, a precipitate will be thrown down, at first of a deep orange, and afterward changing to green. This being dried, and heated with a little sulphur before the blow-pipe, fuses into a globule, from which the sulphur may be expelled by exposing it to the extremity of the flame, and the palladium will remain spongy and malleable.

It may likewise be obtained by dissolving an ounce of nitrate of potash in five of muriatic acid, and in this mixture digesting the compound precipitate mentioned above. Or more simply by adding to a solution of crude platina a solution of prussiate of mercury, on which a flocculent precipitate will gradually be formed, of a yellowish-white colour. This is prussiate of palladium, from which the acid may be expelled by heat.

Palladium is of a greyish-white colour, scarcely distinguishable from platina, and takes a good polish. It is ductile and very malleable; and being reduced into thin slips is flexible, but not very elastic. Its fracture is fibrous, and in diverging striæ, showing a kind of crystalline arrangement. In hardness it is superior to wrought iron. Its specific gravity is from 10.9 to 11.8.

Of Rhodium.

Rhodium exists in crude platina, and was discovered by Dr. Wollaston. It is of a white colour; no degree of heat that has yet been applied to it is capable of melting it, of course many of its properties remain unknown. When united with sulphur it is readily melted; and it forms an alloy with most of the metals except mercury.

Of Iridium.

This substance was discovered by Mr. Tennant in 1803. When crude platina is dissolved in nitro-muriatic acid, a black powder remains, which preceding chemists supposed to be plumbago, but which Mr. Tennant ascertained to be a compound of two new metals. This metal is in appearance like platina, and appears to be as difficult of fusion as that metal, and even more so. It resists the action of the acids; it forms alloys with all the metals tried except arsenic.

Of Osmium.

Osmium was also discovered by Mr. Tennant at the same time with the preceding. It exists in the black powder precipitated during the solution of crude platina. Its name is derived from its peculiar smell. It is of a dark grey or blue colour; resists the action of all the acids; is easily oxidized by heat in the open air; and may be amalgamated with mercury.

Of Copper.

Copper is a metal of a peculiar reddish colour; hard, sonorous, very malleable and ductile, and of great tenacity: specific gravity from 8.6 to 8.9. Besides its employment to make vessels of capacity, and to sheathe the bottom of ships, it is alloyed with zinc to make brass; it is combined with sulphuric acid to form Roman vitriol; and its oxides are employed in enamel painting, and in the manufacture of several colours.

Of Iron.

No metal is so widely diffused through nature as iron, most mineral bodies or stones being found with an admixture of it. Sands, clays, the waters of rivers and springs, are scarcely ever perfectly free from it. The parts of animal and vegetable substances also afford iron in the residues they leave after incineration. In its native state iron is very scarce; most iron being found in the state of oxide, in ochres, and bog-ores, and other earthy substances. The magnet or loadstone is an ore of iron.

Iron is of a bluish white colour, of considerable hardness, and elasticity; very malleable, and exceedingly tenacious. From the intense heat requisite to fuse it, it can only be brought into the shape required by hammering. In a white heat it appears as if covered with a kind of varnish; and in this state two pieces of it when applied together will adhere and may be perfectly united by forging: this process is termed welding, and can be applied to no other metal except platina. Iron is easily oxidized. An iron wire, ignited at one end by a brimstone match attached to it, and plunged into a glass jar of oxygen gas, will be entirely consumed by the successive combustion of its parts.

Highly concentrated sulphuric acid has little effect on iron; but if the acid be diluted with about three parts of water, a violent action takes place, the iron is dissolved, and during the solution large quantities of hydrogen gas escape.

The substances known by the names of steel, and cast-iron, are combinations of iron with different degrees of carbon.

Iron is one of the principal ingredients in dyeing black, and in the manufacture of writing ink. Leather prepared by tanning with oak bark is blackened by a solution of sulphate of iron.

Of Nickel.

Nickel is a metal of great hardness, of a uniform texture, and of a colour between silver and tin; very difficult to be purified, and magnetical. It even acquires polarity by the touch. It is malleable, both cold and red-hot; and is scarcely more fusible than manganese. Its oxides, when pure, are reducible by a sufficient heat without combustible matter; and it is little more tarnished by heating in contact with air than platina, gold, and silver. Its specific gravity, when cast, is 8.279; when forged, 8.666.

Nickel is commonly obtained from its sulphuret, the kufernickel of the Germans, in which it is generally mixed also with arsenic, iron, and cobalt. The alloys which it forms are but imperfectly known: they are brittle and hard, and have never been applied to any useful purpose.

Of Tin.

Tin is of a fine white colour, with a shade of blue: it has a slightly disagreeable taste, and when rubbed emits a peculiar smell. Its specific gravity when hammered is 7.299. It quickly tarnishes when exposed to the air; but is not altered when kept under water. It is the brightest of metals, and very ductile, but at the same time tenacious and flexible. It enters into combination with most other metals, and its alloys are highly useful in the manufacture of hardware goods.

Of Lead.

Lead is of a bluish white colour, and when newly melted is very bright, but soon tarnishes when exposed to the air. It is the softest of all the metals; it does not become harder by hammering; it may be reduced to very thin plates, but its tenacity and ductility are not considerable. The use of lead is very extensive. Of the oxides of lead there are, 1. the powder precipitated by potash from the nitrate of lead; this is termed the yellow protoxide, which, when somewhat vitrified, constitutes litharge, and, when combined with carbonic acid, white lead, or ceruse. 2. When massicot has been exposed for about 48 hours to the flame of a reverberatory furnace it becomes red lead, or minium. 3. If upon 100 parts of red lead we digest nitric acid of the specific gravity 1.26, part of it will be dissolved, the remaining part is peroxide of lead. The specific gravity of lead is 11.407.

Of Zinc.

Zinc is of a brilliant white colour, with a shade of blue, and is composed of thin plates cohering together. It is somewhat harder than silver. Its specific gravity when hammered is 7.1908. Zinc was formerly supposed not to be ductile: but if heated to a little above 212°, it becomes very malleable, and may be drawn into wires. Combined with copper, zinc forms one of the most useful alloys, namely brass.

The sulphuric acid diluted with water dissolves zinc very rapidly; in this process the water is decomposed, and much hydrogen escapes. By evaporating the liquor, sulphate of zinc, or white vitriol, may be obtained in crystals.

Of Bismuth.

Bismuth is of a reddish white colour, and is usually found in silver and tin mines. It is composed of broad brilliant plates adhering to each other, and is harder than silver. Its specific gravity is 9.882. Bismuth is not malleable; it is used chiefly in the composition of pewter, solder, printing types, &c.

Of Antimony.

Antimony is a metallic ore, consisting of sulphur combined with the metal which is properly called antimony. Sometimes this sulphuret is termed crude antimony, to distinguish it from the pure metal, or regulus, as it was formerly called. According to Professor Proust, the sulphuret contains 26 per cent. of sulphur.

Antimony is of a dusky white colour, very brittle, and of a plated or scaly texture. Its specific gravity, according to Brisson, is 6.7021; but Bergman makes it 6.86. Soon after ignition it melts, and by a continuance of the heat it becomes oxidized, and rises in white fumes, which may afterward be volatilized a second time, or fused into a hyacinthine glass according to the management of the heat: the first were formerly called argentine flowers of regulus of antimony. In closed vessels the antimony rises totally without decomposition.

This metallic substance is not subject to rust by exposure to air, though its surface becomes tarnished by that means. Its oxides are a little soluble in water; and in this respect they resemble the oxide of arsenic, by an approach toward the acid state.

Antimony combines readily with the softer metals, and the alloys thus formed have been hitherto applied chiefly in the manufacture of music plates and printing types. Medicine is indebted to antimony for some of its most active and valuable remedies. The acid of tartar forms with it the preparation called antimoniated tartrate of potass, formerly known by the name of emetic tartar.

Of Tellurium.

This metal is of a bluish white colour, its texture laminated, and its brilliancy considerable. It is very brittle; its specific gravity 6.115. It melts a little above the melting point of lead. When exposed to the action of the blow-pipe, it burns with a bluish flame, and is converted into a white oxide. It may be combined with sulphur by fusion, and amalgamated with mercury. The metallic alloys which it is capable of forming are not known.

Arsenic.

Arsenic is generally found in combination with sulphur, oxygen, and many of the metals. When reduced to its pure metallic state, it is a friable, brilliant metal, of a bluish white colour, easily tarnishing, that is, oxydizing, by exposure to the air. In all its states it is poisonous. Arsenic is used to whiten copper, and it enters into most of the compositions for the specula of reflecting telescopes and for other optical purposes. Its oxides are employed in many processes of the dyer, also as fluxes for glass; and in several of the arts. The sulphurets of arsenic form valuable pigments of different colours.

Of Cobalt.

Cobalt is a brittle, somewhat soft, but difficultly fusible metal, of a reddish grey colour, of little lustre, and a specific gravity of 8.6. Its melting point is said to be 130° Wedgewood. It is generally associated in its ores with nickel, arsenic, iron, and copper; and the cobalt of commerce usually contains a proportion of these metals.

Cobalt is susceptible of magnetism, but in a lower degree than steel and nickel.

Of Manganese.

Manganese is a metal of a dull whitish colour when broken, but which soon grows dark by oxidation, from the action of the air. It is hard, brittle, though not pulverizable, and rough in its fracture; so difficultly fusible, that no heat yet exhibited has caused it to run into masses of any considerable magnitude. Its specific gravity is 8.0. When broken in pieces, it falls into a powder by spontaneous oxidation.

The black oxide of manganese is found very generally. It is procured in the greatest purity in the neighbourhood of Exeter, and is very much used for obtaining the oxygenated muriatic acid gas employed in bleaching. It is also used by glass-makers for destroying the green or yellow tint of glass; and for this reason has been called glass-makers' soap. It is also employed for giving a violet colour to glass and porcelain. In a metallic state it is of a grey colour, not at all malleable, and more infusible than iron.

Where oxygen gas is wanted for philosophical experiments, the black oxide of manganese will be found to furnish it, at a cheap rate, in greater abundance than any other substance known to yield it.

Of Chromium.

This metal was first discovered by Vauquelin, who extracted it from the red lead ore of Siberia. Its colour is white, specific gravity 5.90. It is brittle; takes a good polish, and is magnetic, but less so than nickel and cobalt. Both heat and the acids act upon it with difficulty; on this account it has hitherto been met with only in small grains.

Of Uranium.

This metal is but little known, and it appears doubtful if it has ever been obtained in a state of purity, since the different specimens of different chemists have all differed in specific gravity. It has been found in France; and some specimens of great beauty have been found in Cornwall. It is of a grey colour; brittle, and extremely difficult of fusion.

Of Molybdenum.

Molybdenum is a metal which has not yet been reduced into masses of any magnitude; but has been obtained only in small separate globules, in a blackish brilliant mass. This may be effected by making its acid into a paste with oil, bedding it in charcoal in a crucible, and exposing it to an intense heat.

Of Tungsten.

Tungsten is obtained by exposing a mixture of tungstic acid and charcoal to a strong heat. The name given to this metal signifies heavy stone. It is of an iron colour, very hard, and brittle, and difficult of fusion. According to Professor Brande, its specific gravity is 17.5. By the action of heat and air it is converted into an oxide, which is of a yellow colour.

Of Columbium.

This metal, as its name imports, was discovered in a mineral from North America, by Mr. Hatchett. Berzelius appears to be the only person who has succeeded in obtaining Columbium. He describes it as having the colour of iron; as being very hard, and brittle; and burning at a red heat into a whitish oxide.

Of Titanium.

This name was given to a metallic substance discovered by Mr. Gregor in a kind of ferruginous sand found in Cornwall. It is so refractory that most persons have failed in their attempts to reduce it. Lampadius is said to have succeeded. Its colour is that of copper, with a metallic brilliancy; is very brittle, but in small scales it is very elastic.

Of Cerium.

Cerium was obtained by Hisinger and Berzelius from a mineral found in Sweden, to which they gave the name of *Cerite.* This metal is extremely difficult of fusion: Mr. Children, however, succeeded in fusing it by the aid of his powerful voltaic apparatus. It burned with a vivid flame, and was partly volatilized. It is a hard, white, brittle metal.

Of Potassium.

This metal was discovered by Sir H. Davy in 1807. He obtained it by submitting caustic potash to the action of voltaic electricity; the metal was slowly evolved at the negative pole. Potassium is a white metal of great lustre; it is ductile, and of the consistency of soft wax. It is lighter than water, its specific gravity being 0.85. When exposed to the air it instantly tarnishes, and must be kept in pure naphtha. It is a conductor of electricity. When thrown upon water, it acts with great violence, and swims on the surface, burning with a beautiful light of a red colour. The water becomes a solution of pure potash.

On all fluid bodies which contain water, or much oxygen or chlorine, it readily acts; and in its general powers of chemical combination, says its illustrious discoverer, potassium may be compared to the alkahest, or universal solvent, imagined by the alchymists.

Of Sodium.

This metallic substance appears to be the basis of soda, and was discovered by Sir H. Davy a few days after he discovered potassium. It is procured in the same way as potassium, which it resembles in many of its properties. It operates on most substances in a similar manner, but with less energy; and to keep it from tarnishing it must be preserved in naphtha.

Barium.

Barium is the name given by the discoverer, Sir H. Davy, to the metallic basis of the earth barytes. It is obtained by forming pure barytes into a paste with water, and placing the mass on a plate of platinum. A small cavity is then formed in the middle of the barytes, into which a globule of mercury is to be placed. This preparation is then subjected to the action of the voltaic battery, by touching the mercury with the negative wire, and the platinum with the positive wire. In a short time an amalgam is formed consisting of mercury and barium, which, on being distilled in a curved glass tube, free from lead, parts with the mercury, while the barium remains. This metal is of a dark grey colour, inferior in lustre to cast-iron, and fusible at a red heat.

OF LIGHT.

The physical properties of light were considered under Optics. This substance seems to have considerable influence upon many chemical processes. The effect of light upon vegetation is well known. Many flowers follow the course of the sun; and plants that grow in houses seem solicitous to turn to the light. Plants that grow in the shade, or in darkness, are pale, and without colour: and when this is the case, they are said to be etiolated or blanched. Gardeners avail themselves of this fact to render vegetables white and tender. The more plants are exposed to the light, the more colour they acquire. Yet the dead vegetable is deprived of colour by exposure to it.

Vegetables are not only indebted to light for their colour: their taste and odour are derived from the same source. From this cause it happens that hot climates are the native countries of perfumes, odoriferous fruits, and aromatic resins. The action of light on the organs of vegetables causes them to pour out streams of pure air from the surfaces of their leaves, while exposed to the sun: whereas, on the contrary, when in the shade, they emit air of a noxious quality. Even animals, in general, droop when deprived of light; and it appears to be of great importance to the health and happiness of human beings.

CALORIC.

"Caloric, or elementary fire, is the name now given by chemists to that element or property, which, combined with various bodies, produces the sensation of *heat*, while it is passing from one body to another. This substance appears to pervade the whole system of nature. There are six different sources from whence caloric may be procured.

" It may be produced by *combustion*, in which process the oxygen gas of the atmosphere is decomposed, and caloric, one of its component parts, set at liberty—by *friction*, or the rubbing of two substances against each other—by *percussion*, as the striking of steel against a piece of flint—by *the mixture of two or more substances;* as when sulphuric acid is poured upon water or magnesia—by *electricity* and *Galvanism;* the discharge of an electric or galvanic battery will produce a more intense degree of heat than any other means whatever. But the principal and probably the original source of caloric is the sun, which furnishes the earth with a regular supply for the support and nourishment of the animal and vegetable tribes. From this source it moves at the rate of 195,000 miles in a second of time; for, it has been already stated, that the sun sends forth rays of heat, which are distinct from those which produce illumination, and which accompany them in their course through the etherial regions.—Caloric is the cause of *fluidity*, in all substances which are capable of becoming fluid. A certain portion, or *dose* of it, reduces a solid body to the state of an incompressible fluid; a larger portion brings it to the state of an aeriform or gaseous fluid. Thus, a certain portion of caloric reduces ice to a state of water; a larger portion converts it into steam or vapour. There is reason to believe, that the hardest rocks, the densest metals, and every solid substance on the face of the earth, might be converted into a fluid, and even into a gas, were they submitted to the action of a very high temperature. This substance is called *sensible* caloric, when it produces the sensation of *heat;* and *latent* caloric, when it forms an insensible part of the substance of bodies.—All bodies are, in a greater or less degree, *conductors* of caloric. Metals and liquids are good conductors of heat; but silk, cotton, wool, wood, &c. are bad conductors of it. For example, if we put a short poker into the fire at one end, it will soon become hot at the other; but this will not happen with a piece of wood of the same length, and under the same circumstances. A person with a silken purse, containing metal coin, may stand so near the fire, as to make the metal almost too hot to touch, though the temperature of the purse will apparently be scarcely altered. If a hand be put upon a hot body, part of the caloric leaves the hot body and enters the hand, producing the sensation of heat. On the contrary, if a hand be put on a cold body, as a piece of iron, or another colder hand, part of the caloric contained in the hand leaves it to unite with the colder body, producing the sensation of cold. In short, caloric is diffused throughout all bodies, and enters into every operation in nature; and, were it not for the influence of this subtile fluid, there is reason to believe that the whole matter of the universe would be condensed into a solid mass."—*Dick's Christian Philosopher.*

Of Earths.

Those substances known by the name of earths are nine in number, and are by chemists divided into *Alkaline* earths, and earths proper. The leading properties of earths are the following:—

1. Insolubility in water, or at least becoming so when combined with carbonic acid.
2. Little or no taste or smell, at least when combined with carbonic acid.
3. Fixed, incombustible, and incapable, when pure, of being altered by fire.
4. A specific gravity not exceeding 4.9.
5. When pure, capable of assuming the form of a white powder.
6. Not altered when heated with combustibles.

Of the Alkaline Earths.

1. *Lime.*—Lime is seldom found in a pure state; it is contained in chalk, which may be deemed a neutral salt, being formed by the combination of lime with carbonic acid. The best process for obtaining lime in a state of purity is this: wash chalk in distilled water, brought to a state of ebullition, and then dissolve it in distilled acetous acid: this acid, by combining with the lime, expels the carbonic acid, which escapes under the gaseous form; then precipitate the lime by carbonate of ammonia, for the acetous acid abandons the lime, in order to combine with the ammonia, and the lime is precipitated: wash and calcine this precipitate, and the residuum will be pure lime.

Lime is soluble in water, but in very small quantities; more than 600 parts of water are necessary to dissolve one of it. It has a pungent, hot, and acrid taste; it turns blue vegetable colours green. It takes up water with avidity. When thrown into this liquid it splits, swells up, acquires a larger volume, and a great heat. It dissolves in acids without effervescence. The borate of soda and the phosphates of urine dissolve it also.

Lime, when alone, is infusible, even though the fire may be urged by oxygen gas, as has been proved by Lavoisier; but if combined with acids, it forms a fusible body, for lime is a salifiable base. Of all these bases it is that most abundantly diffused throughout nature.

2. *Magnesia.*—Magnesia has never yet been found free from every kind of foreign matter. To procure it in the utmost degree of purity, crystals of the sulphate of magnesia (Epsom salt), of which it forms the base, must be dissolved in distilled water, and decomposed by alkaline carbonates: the sulphuric acid combines with the alkalis; the magnesia with the carbonic acid, and is precipitated. This precipitate must then be calcined, in order to disengage the carbonic acid; and what remains will be pure magnesia.

Pure magnesia is exceedingly white, tender, and in appearance spongy. When perfectly pure it is not sensibly soluble in water. It excites no sensible savour on the tongue; and in this respect it is greatly different from lime.

3. *Barytes.*—Barytes, or ponderous earth, has never yet been found pure and free from all combination. It is found under the pulverulent form, and exceedingly white. It gives a very slight tint of green to blue vegetable colours. Its specific gravity is from 4.2 to 4.3. Analysis has proved that 100 parts of carbonate of barytes contain 62 of barytes, 22 parts of carbonic acid, and 16 parts of water.

4. *Strontian.*—This earth was discovered by Dr. Hope, professor of chemistry at Edinburgh. It is found in the state of a carbonate, that is, combined with carbonic acid, in a vein of lead ore, at Strontian in Argyleshire, in the western part of Scotland. It has been found also combined with carbonic acid at Lead-hills, in the same country. Some of it has since been discovered at Montmartre in France, combined with sulphuric acid; and it is found in quantities in the neighbourhood of Bristol.

Strontian was at first confounded with barytes; which indeed it resembles in several respects, though it differs from it in others.

Carbonate of strontian is decomposed by the sulphuric acid, and carbonic acid is disengaged: the sulphate of strontian, thus obtained, is very little soluble in water. It dissolves with effervescence in the nitric and muriatic acids, and carbonic acid is disengaged. These nitrates and muriates of strontian are not deliquescent, and are decomposed by the sulphates of lime, potash, and others. It may be deprived of its acid by calcination; its earth is then soluble in water, but in greater quantity in boiling than in cold water, for a part of it is precipitated by cooling.

The carbonate of strontian is lighter than carbonate of barytes; the specific gravity of the latter is from 4.2 to 4.3, that of the carbonate of strontian is only from 3.6 to 3.7. Analysis has proved, that 100 parts of the carbonate of strontian contain 62 parts of strontian, 30 parts of carbonic acid, and 8 parts of water.

Of the Earths Proper.

1. *Alumina.*—Alumina, or pure argil, is found chiefly in the different kinds of clay, of which it forms the base, and where it is often mixed with silex. To obtain it very pure, sulphate of alumina (alum) must be dissolved in water, and afterwards decomposed by alkaline carbonates. The alkali combines with the sulphuric acid, which then abandons the alumina; and the latter combines with the carbonic acid abandoned by the alkali. The alumina must then be freed from this acid by calcination; and after this process it will remain pure. It absorbs water with avidity, and becomes diluted in that liquid. It adheres strongly to the tongue. The borate of soda and the phosphates of urine dissolve it. When exposed to heat, it becomes dry, shrinks, and cracks. By the action of the fire it acquires so great hardness as to strike fire with steel: it is then no longer susceptible of being diluted in water. Alumina, even when perfectly pure, is completely fusible in the fire, if urged by a current of

oxygen gas. The result of its fusion is a vitreous, opaque, and very hard substance, which scratches glass in the same manner as precious stones do.

2. *Yttria.*—This earth was discovered by Gadoline in a Swedish mineral, of a black colour, to which the name of Gadolonite has been given. When prepared, it is a fine white powder without taste or smell; it is insoluble in water, and heat does not melt it. It is also insoluble in pure alkalis, but readily soluble in alkalis when carbonated. Sp. gr. 4.842.

3. *Glucina.*—Glucina is a simple earth, lately discovered by Vauquelin, in the aigue-marine, called the occidental. It is a white granulated earth, which effervesces with acids. In 100 parts of the aigue-marine there are 14 of glucina. It is soluble in the carbonate of ammonia, as well as in the sulphuric acid. In the latter case, the solution has at first a saccharine, and afterwards an astringent taste. Its crystals are sweet, like the solution. It has some resemblance to alumina; as it is soft to the touch, adheres to the tongue, is light, dissolves in potash, and is precipitated from its solution by ammonia. But it differs from alumina by its combinations with acids, being exceedingly sweet, by giving no alum when mixed with sulphate of potash, by being entirely soluble in carbonate of ammonia, and by not being precipitated from its solutions by oxalate of potash and tartrite of potash, as alumina is.

It has been found by analysis, that 100 parts of earth contain 68 of silex, 15 of alumina, 14 of glucina, 2 of lime, and of the oxide of iron.

4. *Zirconia.*—Zirconia is a simple earth, lately discovered by Klaproth, in the jargon of Ceylon, of which it is a constituent part, and even the most abundant; for it has been found by analysis, that 100 parts of the jargon of Ceylon contain 64 parts and a half of zirconia, 32 parts of silex, and two parts and a half of the oxide of iron. To obtain zirconia pure, it must be united to the muriatic acid, with which it forms a muriate of zirconia; this muriate must be dissolved on a large quantity of water, and the zirconia must be precipitated by potash: if it is carefully washed, and

then brought to a red heat in a crucible, it will be perfectly pure. Calcined zirconia has a white colour. It is rough to the touch like silex; it has no taste, and is not soluble in water. Its specific-gravity is at least 4.3; that of distilled water being 1.0.

When separated from its solutions by caustic alkalis, this earth retains a pretty large quantity of water, which gives it the semi-transparency of horn; it has then the appearance of gum-arabic, both by its slightly yellow colour and its fracture and transparency. It is susceptible of uniting with carbonic acid. It unites also with the sulphuric and nitrous acids: alkalis, and the first six primitive earths, separate it from the latter acid. It will not alone fuse by the blow-pipe; but it fuses with the borate of soda, and gives a transparent colourless glass.

5. *Silex, or Silica.*—Silex, or vitrifiable earth, is almost in its state of purity in rock-crystal: but to have it perfectly pure, one part of beautiful rock-crystal must be fused with four parts of pure alkali; the mixture must then be dissolved in water, and precipitated by an excess of acid: the precipitate will be pure silex, which is rough and harsh to the touch; its particles, when diluted in water, are easily precipitated.

The fluoric acid dissolves silex exceedingly well: it is also the solvent of glass. Alkalis dissolve silex in the dry way, and with it form glass. Silex cannot be fused by a burning lens; but by exposing it to a fire, urged by oxygen gas, Lavoisier produced a commencement of fusion on its surface.

OF COMPOUND SUBSTANCES.

I. *Water.*—It is scarcely necessary to give any definition or description of this universally known fluid. It is a very transparent fluid, possessing a moderate degree of activity with regard to organized substances, which renders it friendly to animal and vegetable life, for both which it is indeed indispensably necessary. Hence it acts but slightly on the organs of sense, and is therefore said to have neither taste nor smell. It appears to possess considerable elasticity, and yields in a perceptible degree to the pressure of air in the condensing machine, as Canton proved, by including it in an open glass vessel with a narrow neck.

The solubility or insolubility of bodies in this fluid composes a large part of the science of chemistry.

Native water is seldom, if ever, found perfectly pure. The waters that flow within or upon the surface of the earth contain various earthy, saline, metallic, vegetable, or animal particles, according to the substances over or through which they pass. Rain and snow waters are much purer than these, although they also contain whatever floats in the air, or has been exhaled along with the watery vapours.

The composition of water is best demonstrated by exploding 2 volumes of hydrogen and 1 of oxygen, in the eudiometer. They disappear totally, and pure water results.

II. *Alcohol.*—This substance, commonly called *spirit of wine,* is obtained by distillation in a state more ardent and purified than that article. Spirit of wine is obtained by distilling farinaceous or saccharine roots, as well as the pulpy fruit of vegetables; it is purified by repeated rectification, and is called *alcohol* when divested of its aqueous particles. It is chiefly employed in preparing varnishes, in dissolving gum resins, and for various other purposes in medicine. The antiseptic power of alcohol renders it valuable in preserving anatomical preparations. It is also now much used for burning in lamps on account of the steady and uniform heat which it gives during combustion. Fourcroy reckons it to be rectified to the highest point when its specific gravity is 829, water being 1000.

It was long supposed that alcohol could not be solidified by congelation; but it appears from an account given by Dr. Hutton, in the Edinburgh Encyclopedia, that he succeeded in freezing it by a cold of 100°: the process, however, has not been made public.

III. *Oils.*—The distinctive characters of oil are inflammability, insolubility in water, and fluidity, at least in a moderate temperature. Oils are distinguished into fixed or fat oils, which do not rise in distillation at the temperature of boiling water; and volatile or essential oils, which do rise at that temperature with water, or under 320° by themselves.

The volatile oil obtained by attenuating animal oil, by a number of successive distillations, is called Dippel's animal oil.

Monnêt asserts, that, by mixing acids with animal oil, their rectification may be very much facilitated.

The addition of a little ether, before re-distillation of old essential oils, improves the flavour of the product.

IV. *Alkalis.*—The term alkali is now applied to all substances having the following properties:—

1. A caustic taste. 2. Volatilized by heat. 3. Capable of combining with acids, and of destroying their acidity. 4. Soluble in water, even when combined with carbonic acid. 5. Capable of converting vegetable blues to green.

The alkalis at present known are these:—

1. Ammonia; 2. Potash; 3. Soda. The first is called *volatile alkali;* the two last are called *fixed alkalis.* The alkalis will be found more fully described under their respective names.

V. *Acids.*—The name of *acid* is given to all substances, whether liquids or solids, which produce that sensation on the tongue, which we call *sour;* which change the blue juices of vegetables to *red,* and combine with alkalis, earths, or metallic oxides, so as to form those compounds called *salts.* When two acids have the same radical, but contain different quantities of oxygen, each acid is distinguished by its termination. The name of that which contains most oxygen ends in *ic*, the other in *ous.* Thus we say *sulphuric* acid, and *sulphurous* acid; *phosphoric* acid, and *phosphorous* acid. To express the presence of a greater quantity of oxygen, the word *oxygenized* is added to the name of the acid, as oxymuriatic acid (now chlorine).

2. The acids have been divided by Dr. Thomson into acid products, acid supporters, combustible acids, and colorific acids. i. ACID PRODUCTS consist of *sulphuric* acid, formerly called oil of vitriol, and vitriolic acid; *sulphurous* acid; *phosphoric, phosphorous* acids; *carbonic* acid, formerly called fixed air; *boracic* acid,

from the salt called borax; and *fluoric* acid, from the *fluor* spar, or Derbyshire spar. ii. ACID SUPPORTERS, contain *nitric* acid, called aqua fortis and spirit of nitre; *nitrous* acid; *oxymuriatic* acid, or chlorine; and the *arsenic*, *tungstic*, *molybdic*, *chromic*, and *columbic* acids, obtained from the metals arsenic, tungsten, molybdenum, chromium, and columbium. iii. COMBUSTIBLE ACIDS are *acetic* acid, from wine or beer; *benzoic*, from the resin called benzoin; *sebacic*, from fat; *succinic*, from amber; *moroxylic*, from a saline exudation on the bark of the white mulberry tree; *camphoric*, from camphor; *oxalic*, from the wood-sorrel; *mellittic*, from the mellite of honey-stone; *tartaric*, from tartar; *citric*, from oranges and lemons; *kinic*, from a salt in the jesuits' bark; *saclactic*, from sugar of milk; *uric*, in human calculi; *malic*, from apples; *suberic*, from cork; and the *formic*, from the red ant. iv. COLORIFIC ACIDS, or those which cause colour, are the *prussic*, which is the colouring matter of prussian blue, and the *gallic* acid obtained from nut-galls, a concretion formed on the oak in consequence of the puncture of insects. The acids are indispensable in various arts and manufactures; are employed for culinary purposes, and in medicine; and act an important part in the great laboratory of nature.

The preceding may be denominated compounds of the *first order:* and hence those substances which consist of combinations of these are termed compounds of the *second order*, or *doubly compound* substances. These may be reduced to three classes. 1. Soaps. 2. Neutral salts. 3. Hydrosulphurets.

1. *Soaps.* The fixed oils have the property of combining with alkalis, earths, and metallic oxides, and the compounds thus formed have received the name of SOAPS. These soaps differ from each other very materially, according as their base is an alkali, an earth, or a metallic oxide.

2. *Neutral salts.* The term *salt* was originally confined to common salt; it was afterwards generalized by chemists, and applied to all bodies which are sapid, easily melted, soluble in water, and not combustible. It was then confined to acids, alkalis, and the com-

pounds formed by the union of these bodies with each other; but it is now applied to all the compounds which the acids form with alkalis, earths, and metallic oxides. Every species of salt is distinguished by subjoining to the generic term the name of its base. Thus the salt composed of sulphuric acid and soda is called *sulphate of soda.* Triple salts are distinguished by subjoining the names of both the bases. Thus the salt composed of tartaric acid, potash, and soda, is called tartrate of potash and soda.

3. *Hydrosulphurets.* Sulphuretted hydrogen gas possesses many of the properties of an acid, and, like acids, it combines with the salifiable bases, and forms a class of bodies called *hydrosulphurets.* These are of considerable importance, being frequently employed in chemical analyses, to separate the metallic oxides from alkalis and earths. They precipitate almost all the metals from their solutions.

ATTRACTION, REPULSION, AND AFFINITY.

1. *Attraction.* Whenever the force of attraction operates between particles of the same species, it is called the attraction of *cohesion,* or the attraction of *aggregation;* but when between the particles of different qualities and elements, it is then called *chemical* attraction, or affinity of *composition.* It is from the attraction of cohesion that a drop of water is always spherical, and that small particles of quicksilver are constantly of a globular figure. In consequence of the same species of attraction, particles of water and other liquids ascend in capillary tubes. It may be said that the particles of all bodies are possessed of the inherent property of attracting each other, which causes them to adhere, and preserves the various substances around us from falling in pieces. The nature of this wonderful property is entirely unknown. There are different kinds of aggregation; solid, soft, liquid, and gaseous. A stone is an instance of the first, jelly of the second, water of the third, and atmospheric air of the last.

2. *Repulsion.* The only kinds of repulsion that can

be exhibited to the senses are those of electricity and magnetism; but it is *insensible* repulsion with which chemists are more particularly concerned. The chief example of this latter kind that we are acquainted with is the repulsion of the particles of caloric among themselves, which repulsion would constantly tend to infinite separation, were it not for a chemical union, which, by an irrevocable law of nature, they form with the first surrounding body: for by that law, the particles of caloric cannot exist in an isolated state.

3. *Affinity.* Chemical affinity takes place only between the ultimate molecules of bodies: while the attraction of cohesion remains superior to that of affinity, no other union can take place; but whenever caloric has sufficiently diminished this attraction in any substance, the particles are then at liberty to form new combinations, by their union with the particles of other bodies.

Crystallization. The word crystal originally signified ice; but it was afterwards applied to crystallized silica, or rock crystal. Chemists have applied the word to all transparent bodies of a regular shape; and at present it is employed to denote in general the regular figures which bodies assume when their particles have full liberty to combine according to the laws of cohesion. These regular bodies occur very frequently in the mineral kingdom, and have long attracted attention on account of their great beauty and regularity. By far the greater number of the salts assume a crystalline form; and as these substances are mostly soluble in water, we have it in our power to give the regular shape of crystals in some degree at pleasure.

All the substances with which we are acquainted may be divided into solid, liquid, and gaseous. Crystals are obviously confined to the first set, the fluidity of the two last rendering them incapable of retaining a regular form; but many of them may be made to assume a solid state, and in that case they usually crystallize. Most solid bodies either occur in the state of crystals, or are capable of being made to assume that form. There is a particular form which every substance always affects when it crystallizes. Thus common salt is observed to assume the shape of a cube; and alum that of an octahedron, consisting of two four-sided pyramids, applied base to base. Salt-petre assumes the form of a six-sided prism; sulphat of magnesia that of a four-sided prism; and carbonate of lime that of a rhomboid. This, however, is liable to considerable variations, according to the circumstances of the case; but there are a certain number of forms peculiar to every substance; and the crystals of that substance, in every case, adopt one or other of these forms, and no other.

As the particles of bodies must be at liberty to move before they crystallize, it is obvious that we cannot reduce any bodies to the state of crystals, except those which we are able to make fluid.

Solution is the common method of crystallizing salts. They are dissolved in water; the water is slowly evaporated; the saline particles gradually approach each other, combine together, and form small crystals; which become constantly larger by the addition of other particles, till at last they fall by their gravity to the bottom of the vessel. Or a saturated solution being prepared in hot water, it is set by to cool. On the escape of the caloric, by which the solution was in great part accomplished, the salt crystallizes. Such salts commonly form in groups, attached to the sides or bottom of the vessel, or depending from a pellicle. They usually contain more water of crystallization than the former class.

There are many substances, however, neither soluble in water nor other liquids, which, notwithstanding, are capable of assuming a crystalline form. This is the case with the metals, with glass, and some other bodies. The method employed to crystallize them is fusion, which is a solution by means of caloric alone. By this method particles are separated from one another; and if the cooling proceeds gradually, they are at liberty to arrange themselves in regular crystals.

As to the theory of crystallization it may be sufficient here to remark that Haüy, and other chemists of eminence, have assumed that the primitive molecules of matter have three distinct forms, viz. the tetraedron, the simple prism, and the cube; and that these figures form every crystal in nature, and by a certain arrangement with respect to each other, completely fill space. This theory has been found insufficient to account for all the phenomena attending the process of crystallization.

Dr. Wollaston, in order to obviate the difficulties thence arising, has ingeniously proposed to consider the primitive particles of matter as spheres, which, by mutual attraction, have assumed that arrangement which brings them as near as possible to each other. This, however, must be understood with limitation. Dr. Wollaston does not consider the particles as perfectly spherical, but, like Haüy, divides their forms into three classes, viz. the sphere, the spheroid, and the oblong sphere, or ellipsoid. Others are of opinion that the primitive particles of matter are perfectly spherical. This opinion was, we believe, originally advanced, and very ingeniously supported by Mr. Gurney in his lectures at the Surrey Institution.

Great attention has of late been paid to the measuring of the angles of crystals. The instrument used for this purpose is called a goniometer, of which there are two kinds.

1. The goniometer of M. Carangeau, used by M. Haüy, consists of two parallel blades, jointed like those of scissors, and capable of being applied to a graduated semicircular sector, which gives the angle to which the joint is opened, in consequence of the previous apposition of the two blades to the angle of the crystal.
2. The reflective goniometer of Dr. Wollaston; an admirable invention, which measures the angles of the minutest possible crystals with the utmost precision.

CHEMICAL OPERATIONS AND INSTRUMENTS.

The reduction of solids into powders of different degrees of fineness, by *pulverization*, &c. is necessary previously to their being chemically acted upon. But these processes can never reduce substances into their primary or elementary particles: they do not even destroy the aggregation of bodies. The real chemical operations, on the contrary, separate their constituent particles from each other. Brittle substances are reduced to powder by means of hammers, pestles and mortars, stones, and mullers. Wedgewood's ware affords a most excellent kind of mortar for most purposes, as it is very strong, and not liable to be acted upon by acids. Many bodies cannot be reduced to powder by the foregoing methods: such are fibrous substances, as wood, horns of animals, elastic gum, and metals which flatten under the hammer; for these, files, rasps, knives, and graters, are necessary.

The separation of the finer parts of bodies from the coarser is performed by means of sifting or washing.

Washing is used for procuring powders of a uniform fineness. The powdered substance is mixed with water, or some other convenient fluid: the liquor is allowed to settle, and is then decanted off; the coarsest powder remains at the bottom of the vessel, and the finer passes over with the liquor. By repeated decantations in this manner, various sediments are obtained, of different degrees of fineness; the last being the finest.

Filtration is a finer species of sifting. It is sifting through the pores of paper, or flannel, or fine linen, or sand, or pounded glass, or porous stones, and the like; but is used only for separating fluids from solids, or gross particles that may happen to be suspended in them, and not chemically combined with the fluids. Unsized paper is a very convenient substance for making filters for chemical purposes. It is wrapped up in a conical form, and put into a glass funnel, which serves to strengthen the paper and support the weight of the fluid when poured into it.

Decantation is often substituted instead of filtration, for separating solid particles which are diffused through liquors. If the sediment is extremely light, and apt to mix again with the fluid, a syphon is used for drawing off the clear fluid.

Lixiviation is the separation by means of water, or other fluid, of such substances as are soluble in it, from those which are not. Thus, if a mineral consists of salt and sand, or salt and clay, &c. the given body being broken to powder, is placed in water, which will dissolve the salt, and keep it suspended, whilst the earthy matter falls to the bottom of the vessel, and, by means of filtration, may be separated from the fluid.

Evaporation separates a fluid from a solid, or a more volatile fluid from another which is less volatile.

Simple evaporation is used when the more volatile or fluid substance is not to be preserved. Various degrees of heat are employed for this purpose, according to the nature of the substances. It is performed in vessels of wood, glass, metal, porcelain, &c. Basins made of Wedgewood's ware are very convenient, as they are not apt to break by sudden changes of heat.

When the fluid which is evaporated must be preserved, then the operation is called *distillation*.

Crystallization.—When a salt is dissolved in water, or other fluid, and by evaporation the fluid is driven off, the salt gradually acquires the solid form, and in doing this, it arranges its particles in different figures Vessels of earthen-ware, or glass, are employed for such crystallizations.

Solution.—When a salt is mixed with water, it loses its state of solidity: the particles of salt are divided, and unite themselves to those of the water. The same takes place when resin is mixed with spirits of wine. In this process neither the salt nor the water is decomposed; and the salt may be recovered again in its original state and quantity, by evaporation.

The dissolution of metals by acids, however, is of a different nature; here, either the metal, the acid, or the water, is altered, and different products are obtained. Vessels of glass are generally used for solutions and dissolutions. The liquid used for dissolving a metal, or other solid substance, is usually called a solvent, or menstruum.

Precipitation.—The recovery or separation of a body from its solvent, by the addition of a third substance, so that the former may re-appear in a solid state, however divided, is called precipitation. The substance thus recovered is called a precipitate, and the superadded body that occasions this precipitation is called a precipitant.

Fusion.—The melting of any body from the solid to the liquid state, by the action of fire, is called fusion. The fusion of metallic substances requires vessels sufficiently strong to resist the fire. These are mostly, if not always, made of earthen-ware, or porcelain. or a mixture of clay and powder of black-lead, and are called crucibles. Sometimes they have covers, but others are broad and shallow, that the fused metal may be exposed to a current of air. These are named cupels; and are placed under a sort of oven, made of earthen-ware, called a muffle; with which the included cupel is exposed to the heat of the furnace.

Furnaces.—In the application of the action of heat to bodies, furnaces of different forms are employed, according to the operations for which they are intended. A furnace is a kind of hollow cylindric tower; sometimes a little wider at the top, with notches to give a passage to the air. This furnace ought to have at least two lateral apertures; an upper one which is the door of the fire-hole, and a lower one which is the door of the ash-hole. In the interval between these doors the furnace is divided into two parts by a horizontal grate for supporting the charcoal.

Another kind of furnace, often necessary, is that called the reverberating furnace; it consists of an ash-hole, a fire-hole, a laboratory, and a dome. In the laboratory is placed a retort, which is supported by two iron bars that run across the furnace; the neck of it passes through a lateral aperture, and has adapted to it a receiver. As a strong heat is sometimes required for this furnace, a large volume of air must be made to pass through it; and in that case a great deal of heat is disengaged. The use of the dome is to reverberate the heat and flame on the retort, in order that it may every where be exposed to nearly an equal heat.

CHEMICAL APPARATUS.

Where chemical experiments are carried to any extent, a good apparatus becomes indispensable; at the same time much may be done by the judicious use of a few of the most necessary articles, of which the following is a brief description.

Figures, 1, 2, 3, plate XV. are crucibles or pots, made either of fire-clay, black-lead, forged iron, or platina. They are used for roasting, calcination, and fusion.

Figs. 4, 5, 6, are cucurbits, matrasses, or bodies, which are glass, earthen-ware, or metallic vessels, usually shaped like an egg; and open at top. They serve the purposes of digestion, evaporation, &c.

Retorts are globular vessels of earthen-ware, glass, or metal, with a neck bended on one side. Some retorts have another neck or opening at their upper part, through which they may be charged, and the opening may be afterwards closed with a stopple. These are called tubulated retorts. A Welter's tube of safety may be inserted in this opening, instead of a stopple. See figs. 7, 8, *b*, *c*.

Receivers are vessels, usually of glass, of a spherical form, with a straight neck, into which the neck of the retort is usually inserted. When any proper substance is put into a retort, and heated, its volatile parts pass over into the receiver, where they are condensed. See fig. 9.

Fig. 10. The alembic is used for distillation, when the products are too volatile to admit of the use of the last mentioned apparatus. The alembic consists of a body, *a*, to which is adapted a head, *b*. The head is of a conical figure, and has its external circumference or base depressed lower than its neck, so that the vapours which rise, and are condensed against its sides, run down into the circular channel formed by its depressed part, from whence they are conveyed by the nose or beak *c*, into the receiver *d*.

Fig. 11 represents an elegant chemical apparatus, of the same nature as that used by Sir H. Davy at the Royal Institution.

A is a japanned tin vessel, filled within two or three inches of the top with water. Just below the surface of the water is fixed a shelf, having several holes bored through it, to which small funnels are attached underneath. The glass receiver B, intended to receive the gas, is filled with water, and being inverted with its mouth under water, it is raised up gently, and placed upon the shelf over one of the holes, where it will remain full of water, which is kept up by the pressure of the atmosphere, in the same way as the mercury is retained in the tube of a barometer.

The materials from which the gas is to be disengaged are put into the retort G, which is passed through and suspended in one of the rings of the lamp-furnace. AE is an improved Argand's lamp, having two concentric wicks, placed on a shelf, which is moveable up and down to bring the lamp to a convenient distance from the retort. The lamp is to be lighted, and as soon as the substances in the retort act upon each other, the gas will begin to be disengaged, and will ascend through the hole of the shelf into the vessel B, and displace or force down the water with which it had been filled. When the water is displaced, the receiver is full of gas, which may be preserved in it, by keeping its mouth always under water in the cistern.

The gas so obtained may be transferred from the vessel B to any other, in the following manner: Fill the vessel into which the gas is to be transferred, with the fluid in the trough, and place it on the shelf, over one of the holes. Then take the vessel B, and, keeping its mouth still under the fluid, bring it beneath the hole above which the vessel to be filled is placed; then by depressing its bottom, and elevating its mouth so as to bring it to a horizontal position, the gas in it will escape, and rise up through the hole, on which the other has been placed, and will fill it by displacing the water.

When the gas to be procured is absorbed by water, as carbonic acid gas, quicksilver is used instead of water, to fill the trough, and a much smaller vessel than A, made of stone or wood, is used. See fig. 12.

A small glass vessel, capable of containing an ounce measure, is used for measuring gases; if this phial be successively filled, and emptied under a larger jar, we may thereby throw into that jar whatever quantity of gases, or any mixture of them, we please.

Adjoining the receiver B, and on the shelf, fig. 11, is a strong glass tube, for receiving a mixture of gases, intended to be exploded by means of the electrical spark. Near the upper end, which is closed, two pieces of brass wire pass in the tube; they are cemented in, so as to make the holes air-tight, and they nearly touch each other within the tube. If the interval between the two wires be made a part of the electric circuit, by putting chains, connected with a Leyden phial, to the hooked ends of the wires, the electric spark will pass through the interrupted space between the two wires, and explode the gases.

Sometimes it is requisite to obtain separately the condensable fluid that comes over, and the gases that are, and are not, soluble in water. For this purpose a series of receivers, more or less in number, as the case may require, is generally employed, as in fig. 13, which represents what is called Woolfe's apparatus, though in fact its original inventor was Glauber, with some subsequent improvements. The vapour that issues from the retort being condensed in the receiver *a*, the gas passes on through a bent tube into the bottle *c*, which is half filled with water. The gas not absorbed by this water passes through a similar bent tube to *d*, and so on to more, if it be thought necessary; while the gas that is not absorbed by water, or condensable, at its exit from the last bottle is conveyed by a recurved tube into a jar *g*, standing in a mercurial trough *ff*.

In chemical experiments the blow-pipe is of essential utility. This instrument is now variously constructed. The blow-pipe for philosophical purposes is provided with a bowl, or enlargement, *a*, fig. 1. Plate XVI, in which the vapours of the breath are condensed and detained; and also with three or four small nozzles, *b*, with different apertures, to be slipped on the smaller extremity.

A wax candle, of a moderate size, but thicker wick than they are usually made with, is the most convenient for occasional experiments; but a tallow candle will do very well. The candle should be snuffed rather short, and the wick turned on one side toward the object, so that a part of it should lie horizontally. The stream of air must be blown along this horizontal part, as near as may be without striking the wick. When the hole is of a proper figure, and duly proportioned, the flame consists of a neat luminous blue cone, surrounded by another flame of a more faint and indistinct appearance. The strongest heat is at the point of the inner flame.'

The body intended to be acted on by the blow-pipe ought not to exceed the size of a peppercorn. It may be laid upon a piece of close-grained, well-burned charcoal, unless it be of such a nature as to sink into the pores of this substance, or to have its properties affected by its inflammable quality. Such bodies may be placed in a small spoon made of pure gold, or silver, or platina.

A very ingenious contrivance by Mr. Hooke, sometimes called the self-acting blow-pipe, is represented fig. 2. Here, *a* is a hollow sphere for containing alcohol, resting upon a shoulder in the ring *o*. If the bottom be made flat instead of spherical, the action of the flame will then be greater. *b* is a bent tube with a jet at the end, to convey the alcohol in the state of a vapour into the flame at *q*. This tube is continued in the inside up to *c*, which admits of *a* being filled nearly, without any alcohol running over. *d* is a safety valve, the pressure of which is determined at pleasure, by screwing higher or lower on the pillar *e*, the two milled nuts *f* and *g* carrying the steel arm *h*, which rests on the valve. *i* is an opening for putting in the alcohol. *k* is the lamp, which adjusts to different distances from *a*, by sliding up or down the two pillars *l l*. The distance of the flame *q* from the jet is regulated by the pipe which holds the wick being a little removed from the centre of the brass piece *m*, and of course revolving in a circle. *n* the mahogany stand.'

The greatest improvement, however, that this instrument has undergone, was introduced by Mr. Gurney, in his lectures delivered at the Surrey Institution, of which a full account may be seen in the published volume.

An indispensable article of apparatus in the laboratory is the gasometer, which enables the operator to receive and preserve large quantities of gas, with the aid of only a few pounds of water. Gasometers are made of different forms; but one of the most simple and most convenient is shown in fig. 3. It consists of an outer fixed vessel, *d*, and an inner fixed one, *c*, both of japanned iron. The inner vessel slides easily up and down within the outer, and is suspended by cords passing over pulleys; to which are attached the counterpoises *e e*. To avoid the inconvenience of a great weight of water, the outer vessel is made double, or is composed of two cylinders, the inner of which is closed at the top, and open at the bottom.

The space only of about half an inch is left between the two cylinders, as shown by the dotted lines. In this space the vessel *c* may move freely up and down. The interval is filled with water as high as the top of the inner cylinder. The cap or rim on the top of the outer vessel is to prevent the water from overflowing when the vessel *c* is forcibly pressed down, in which situation it is placed whenever gas is about to be collected. The gas enters from the vessel in which it is produced by the communicating opening *b*, and passes along the perpendicular pipe marked by dotted lines in the centre into the cavity of the vessel *c*, which continues rising till it is full.

To transfer the gas, or to apply it to any purpose, the cock *b* is to be shut, and an empty bladder, furnished with a stop-cock, is to be screwed on *a*. When the vessel *c* is pressed down by the hand, the gas passes down the central pipe, which it had before ascended, and its escape at *b* being prevented, it finds its way up a pipe which is fixed on the outer surface of the vessel, and which is terminated by the cock *a*.

By means of an ivory mouth-piece screwed on this cock, the gas included in the instrument may be respired, the nostrils being closed by the fingers.

When it is required to transfer the gas into glass jars standing in water, a crooked tube may be employed, one end of which is screwed upon the cock *b*, while the other aperture is brought under the inverted funnel, fixed into the shelf of the pneumatic trough. The counterpoises *e e* are generally concealed in the framing, and the vessel *c* is frequently made of glass.

Fig. 4 represents the combustion of iron wire in oxygen gas. If a fine iron wire, *a*, twisted in the form of a cork-screw, having an ignited sulphur match attached to it, be plunged into a jar of oxygen gas, *b*, a most brilliant and rapid scintillating combustion takes place, forming oxide of iron. In this process, such is the greatness of the heat, that the small globules of the melted metal often penetrate the sides of the jar, if permitted to strike against them.

One of the most extensively useful and convenient articles of chemical apparatus is what is termed the bell-glass and bladder apparatus, see fig. 5.

It consists of a bell-glass, *a*, furnished with a brass cap and stop-cock, *b*. *c* is a small connecting piece, with two female screws, by means of which a second stop-cock, *d*, affixed to a bladder, *e*, or to any other vessel, may be connected with the stop-cock, *b*, and the receiver, *a*. If the bladder, *e*, has been previously compressed, and a communication be then made with the bell-glass, *a*, by opening both stop-cocks, the gas contained in the bell-glass may of course be transferred into the bladder; by pressing down the bell-glass, *a*, into the water of the pneumatic trough, the gas will be forced up into the bladder; the stop-cocks being then shut, the bladder must be removed.

Fig. 6 is a brass tobacco-pipe, furnished with a stop-cock, that it may be connected with a bladder, for throwing up soap bubbles, filled with hydrogen gas, or with a mixture of hydrogen and oxygen gas, for explosion.

Fig. 7 represents a deflagrating ladle for burning small portions of phosphorus, sulphur, &c. in oxygen gas. Fig. 8 shows the same in a jar. Fig. 9 shows the method of raising oxygen gas from the black oxide of manganese. Fig. 10 is a chemical thermometer, and fig. 11 a tube blown with a ball in the middle for dropping liquids.

CHAPTER XIV.

METEOROLOGY.

METEOROLOGY is the science of studying the variable phenomena of the atmosphere. The atmosphere may be considered in respect of the direction of its currents or winds; of the variations in its gravity or pressure; of the changes in its temperature; of the state of the electricity which it exhibits; and lastly, as to the visible phenomena which are supposed to depend on the foregoing.

It is singular that this science should have remained for so long a period in a state of comparative neglect, when it is recollected that almost all the operations necessary for the support of human life, and almost all the comforts of corporeal feeling, depend upon the state of the atmosphere, and yet nothing was attempted to any purpose towards investigating the laws of meteorology till the seventeenth century, when the most important discoveries of the barometer and thermometer occurred, which was followed in the eighteenth by the invention of excellent hygrometers and electrometers; by these the philosopher finds himself competent to make accurate and satisfactory observations. Scientific persons, who have particularly turned their attention to this pursuit, have undertaken the laborious task of collecting and methodically arranging numbers of the observations just mentioned, and after attentively comparing and examining them, have formed theories of the weather of more or less probable accuracy; but the science is of such difficulty, that though those theories deserve every praise, it must be acknowledged that the phenomena of the weather are still very imperfectly understood.

Of Winds.

Winds, though proverbially uncertain in some climates, are yet not without a striking degree of regularity and system, if we consider the whole atmosphere; and there is a part of the world where the wind is so constantly in one quarter, that *windward*, in common speech, stands for eastern, and *leeward* for western. We want only a more extensive set of observations to render exceedingly probable the following hypothesis: That a large portion of the whole atmosphere moves constantly from east to west round the earth, on and near the equator; that this is supplied and impelled by air from the temperate and cold latitudes on each side towards the poles; which again receive, by a superior current, the overflow of the tropical regions, where the air, rarefied by the heat, is constantly rising, and tending to lateral diffusion. Winds appear usually to begin at that point towards which they blow. They must therefore be owing to a rarefaction or displacing of the air in some particular quarter, either by the action of heat, or some other cause.

In 1740, Dr. Franklin was prevented from observing an eclipse of the moon at Philadelphia by a north-east storm, which came on about seven o'clock in the evening. He was surprised to find afterwards, that it had not come on at Boston till near eleven o'clock: and he found it to be always an hour later the farther north-east for every 100 miles. "From thence," says he, "I formed an idea of the course of the storm, which I will explain by a familiar instance. I suppose a long canal of water stopped by a gate. The water is at rest till the gate is opened; then it begins to move out through the gate; and the water next the gate is first in motion, and moves on towards the gate, and so on successively, till the water at the head of the canal is in motion, which it is last of all. Thus, to produce a north-east storm, I suppose some great refraction of the air in or near the Gulf of Mexico; the air rising thence has its place supplied by the next more northern, cooler, and therefore denser and heavier air; a successive current is formed, to which our coast and inland mountains give a north-eastern direction."

This north-east wind blows most frequently with us during the spring months; and from the observations made by Captain Cook, it appears, that the same wind prevails during the same period in the Northern Pacific. Hence it appears, that at that season the cold air from the north of Europe and America flows into the Atlantic and Pacific.

It is very common to observe one current of air blowing at the surface of the earth, while a current flows in a contrary direction in the higher strata of the atmosphere. Three such winds have been observed blowing in contrary directions all at the same time. It is affirmed, that changes of weather generally begin in the upper strata of the air, the wind which blows there gradually extending itself to the surface of the earth.

Were it not for this agitation of the air, putrid effluvia arising from the habitations of man, and from vegetable substances, besides the exhalations from water, would soon render it unfit for respiration, and a general mortality would be the consequence. The temperate zones are not under the influence of so regular winds as between the tropics: the *trade wind* prevails annually and regularly in those parts of the Pacific and Atlantic Oceans which lie near the equator; it blows from the north-east within a few points on the north side of the equator, and from the south-east on the opposite side, and the interval space of these separate winds is from the second to the fifth degree of north latitude, and within the limits just mentioned, where the wind may be said never to blow from the north or the south; but there are dreadful storms, and perfect calms, equally dangerous and perplexing to the mariner, who finds the force of the trade winds decline as he approaches their boundary. 'Between the tenth and thirtieth degrees of south latitude the trade wind prevails in the Indian Ocean; but north of it there is a change every half year, when they blow in an opposite direction to their previous course: these are termed monsoons, and their change is constantly productive of variable airs and storms of extreme violence, which frequently continue from five to six weeks, during which period the navigation is very dangerous. The monsoons take place one on the south and the other on the north side of the equator in the Indian Ocean, and they extend to the eastern coast of China, and the longitude of New Holland, from Africa: they, however, suffer partial changes through local circumstances. They are, besides, not altogether confined to the space just mentioned, as the wind blows from the east or north-east between September and April, and for the remainder of the year from the south-west on the coast of Brazil, between Cape St. Augustine and the Isle of St. Catherine. Having thus directed the attention of the reader to this part of the subject, we shall pass to the prevailing winds of our native country, which were ascertained by order of the Royal Society of London, which learned body published the following result in their Transactions.—At London,

Winds.	Days.	Winds.	Days.
South-west	112	South-east	32
North-east	58	East	26
North-west	50	South	18
West	53	North	16

The same register shows, that the south-west wind blows more upon an average in each month of the year than any other, particularly in July and August; that the north-east prevails during January, March, April, May, and June, and is most unfrequent in February, July, September, and December; the north-west occurring more frequently from November to March, and less so in September and October than in any other months. In the fifth volume of the Statistical Account of Scotland, there is a table of seven years' close observation made by Dr. Meek, near Glasgow, the average of which is stated as follows:—

Winds.	Days.	Winds.	Days.
South-west.........	174	North-east.........	104
North-west.........	40	South-east............	47

In Ireland the prevailing winds are the west and south-west. The different degrees of its motion next excites our attention; and it seems almost superfluous to observe, that it varies in gradations from the gentlest zephyr, which plays upon the leaves of plants, gently undulating them, to the furious tempest, calculated to inspire horror in the breast of the most callous: it is also a most remarkable fact, that violent currents of air pass along, as it were within a line, without sensibly agitating that beyond them.

OF THE PRESSURE OF THE AIR.

With regard to the pressure of the atmosphere, it is every where variable, as appears by the barometer; which indicates to us the weight of a column of air, extending to the top of the atmosphere, and whose base is equal to that of the mercury. At the level of the sea, where the column of air is longest, the mean height of the barometer is thirty inches. The mean height of the barometer is less, the higher any place is situated above the level of the sea, because the column of air which supports the mercury is the shorter.

Between the tropics the variations of the barometer are exceedingly small; and it does not descend above half as much for every 200 feet of elevation as it does beyond the tropics. As the latitude advances toward the poles, the range of the barometer gradually increases, till at last it amounts to two or three inches. This will appear, from the following table:—

Table of the Range of the Barometer.

Latitude.		Places.	Range of the Barometer.	
			Greatest.	Annual.
0°	0′	Peru	0.20	—
22	23	Calcutta	0.77	—
33	55	Cape Town	—	0.89
40	55	Naples	1.00	—
51	8	Dover	2.47	1.80
53	23	Liverpool	2.89	1.96
59	56	Petersburg	3.45	2.77

In North America, however, the range of the barometer is a great deal less than in the corresponding European latitudes. In Virginia, for instance, it never exceeds 1·1. The range of the barometer is greater at the level of the sea than on the mountains; and in the same degree of latitude, the extent of the range is in the inverse ratio of the height of the place above the level of the sea.

The density of the atmosphere is greatest at the poles, and least at the equator; as the centrifugal force at the latter, the distance from the centre of the earth, and the heat, contributing to lessen the density of the air, are at their maximum, when at the pole it is exactly the reverse. In every part of the world the mean height of the barometer placed at the level of the sea will be found to be 30 inches, consequently the weight of the atmosphere is the same in all places; its weight depending on its density and height, where the former is greatest the height must be the least, and where its density is least the height is the greatest. It will therefore appear that the height of the atmosphere must be least at the poles, and greatest at the equator, decreasing gradually in the interval, and thus forming the resemblance of two inclined planes, meeting at the highest part above the equator.

The difference of the mean heat between the pole and the equator, when the sun is in our hemisphere in the summer, does not vary so much as in the winter, as the heat at that period in northern countries equals that of the torrid zone.

The pressure of the superincumbent column in a great measure causes the density of the atmosphere, and therefore decreases in proportion to the height as the pressure of the column constantly decreases, yet the density in the torrid zone does not decrease so rapidly as in the temperate and frigid, as the column is longer, and because there is a larger proportion of air in the upper part of it.

The density at the equator, though less at the surface of the earth, must equal at a certain height, and still higher exceed the density in the temperate zones, and at the poles; but a current of air constantly ascends at the equator, part at least of which reaches to and remains in the highest parts of the atmosphere; but the fluidity of that body prevents it from accumulating above the equator, and hence it must descend the inclined plane before mentioned. The surface of the atmosphere being more inclined in the northern hemisphere during our winter than that of the southern, more of the current must flow on the northern than on the southern, from which cause the quantity of our atmosphere is greater in winter than that of the southern hemisphere; in the summer it is just the contrary.

The heat of any given place in a great measure influences the density of its atmosphere; that density will be most considerable where it is coldest, and its column shortest. Chains of mountains, the summits of which are covered with snow great part of the year, and highlands, must be colder than places less elevated in the same latitude, and the column of air over them much shorter. The current of air above must be impeded and accumulated while on its passage over these places towards the poles.

After the accumulations have existed some time, the surrounding atmosphere becomes incapable of balancing the density of the air, when it descends with violence, and occasions cold winds, which raise the barometer. It is to this that we are to attribute the rise of the barometer almost always attending north-east winds in Europe, which is the effect of accumulations near the pole, or in the north-west parts of Asia.

When in the polar regions large quantities of air are casually compressed, the southern atmosphere must rush in to replace it, which occasions south-west gales, and the fall of the barometer.

The mean heat of our hemisphere varying in successive years, the density of the atmosphere, and, necessarily, the quantity of equatorial air passing towards the poles, cannot be otherwise than variable; hence occur the different ranges of the barometer in successive years; at some particular periods more considerable accumulations take place in the highest parts of Asia and the south of Europe than at others, which may be produced by early falls of snow, or the interruption of the sun's rays by long continued fogs; at such times the atmosphere in the polar regions becomes proportionably lighter, and this causes the prevalence of southerly winds in some winters more than in others.

The heat of the torrid zone never greatly varying, the height and density of the atmosphere undergoes but few changes; thence arises the comparatively small range of the barometer within the tropics, which gradually increases towards the poles, as the difference of the temperature and the density of the atmosphere increase with the latitude. The sinking of the barometer preceding violent tempests, and the oscillations during their continuance, prove that very great rarefactions, or even destruction of air, in some parts of the atmosphere, produce those phenomena; the fall too that accompanies winds arises from the same cause.

OF TEMPERATURE.

There are considerable variations in the temperature of the air in any particular place, exclusive of the difference of the seasons and climates, which change cannot be produced by heat derived from the sun, as its rays concentrated have no kind of effect on air; those, however, heat the surface of our globe, which is communicated to the immediate atmosphere: it is thus that the temperature is highest where the place is so situated as to receive with most effect the rays of the sun, and that it varies in each region with the season; it is also the cause why it decreases in proportion to the height of the air above the surface of the earth. The diminution of temperature from the pole to the equator takes place in arithmetical progression; or the annual temperature of all the latitudes are arithmetical means between, the mean annual temperature of the equator and the pole.

The mean temperature of the equator being 84 deg. and that of the pole 31 deg. to find the mean annual temperature for every other latitude, we have only to find 88 arithmetical means between 84 and 31.

It has been found that in every degree of north latitude, January is the coldest month; July the warmest in all above 48 deg.; in lower, August. Every latitude where existence can be maintained has a mean of 60 deg. two months of the year at the least, which is requisite for the production of those articles by which man supports life. The temperatures within ten degrees of the poles vary little, and the case is similar within the same distance from the equator; those of different years near the latter differ very little, but the differences increase as the latitudes approach the poles. The temperature of the atmosphere likewise diminishes gradually in proportion to its height above the level of the sea.

Mr. Kirwan shows that the rate of diminution depends upon the precise temperature of the surface of the earth where an experiment is made.

This gradual approach to cold demonstrates that at a certain height eternal congelation must prevail; that height varies of course according to the latitude of the place, being highest at the equator and gradually descending on approaching the poles; it is also lower in the winter. The cold on the summit of Pinchinca was found by M. Bouguer to extend, every morning previous to the rising of the sun, from seven to nine below the freezing point; from which he conjectured, that the mean height of the term of congelation (or that region where water congeals on some part of every day in the year) between the tropics is 15,577 feet above the level of the sea; in latitude 28 deg. he supposes it to be 43,440 during summer. Taking the difference between the freezing point and the temperature of the equator, it appears, that it bears the same proportion to the term of congelation at the equator that the difference the mean between the temperature of any other degree of latitude and the freezing point bears to the term of congelation in that latitude.

Estimating the diminution from this method, we find that heat lessens in an arithmetical progression: and from the same premises it may be concluded, that the warmth of the air at some distance from the earth is not to be attributed to the raising of heated strata of air from the earth's surface, but to the conducting power of the air.

The upper strata of the atmosphere are frequently warmer in winter than the lower, and the preceding rule is applicable to the temperature of the air during the summer months only. According to the Philosophical Transactions for 1777, a thermometer placed on the summit of Arthur's Seat, the 31st of January, the year before, stood six degrees higher than a second at Hawk's Hill, situated 684 feet below it: this superior heat is considered by Mr. Kirwan to be produced by a current of heated air flowing from the equator towards the north pole during our winter.

It has been a generally received opinion, that the southern hemisphere, beyond the 40th degree of latitude, is much colder than the corresponding parts of the northern: this is true only with respect to the summer of the former; but the winter in the same latitude is milder than in the latter.

Inconsiderable seas, in temperate and cold climates, are colder in winter and warmer in summer than the standard ocean, as they are necessarily under the influence of natural operations from the land, and its temperature.

Continents have a colder atmosphere than islands situated in the same degree of latitude; and countries lying to the windward of the superior classes of mountains, or forests, are warmer than those which are to the leeward. Earth always possessing a certain degree of moisture, has a greater capacity to receive and retain heat than sand or stones; the latter therefore are heated and cooled with more rapidity: it is from this circumstance that the intense heats of Africa and Arabia, and the cold of Terra del Fuego, are derived. The temperature of growing vegetables changes very gradually; but there is a considerable evaporation from them: if these exist in great numbers, and congregated, as in forests, their foliage preventing the rays of the sun from reaching the earth, the immediate atmosphere must be greatly affected by the ascent of chilled vapours.

OF LIGHTNING AND THUNDER.

Air is one of those bodies which have received the name of electric; it not only contains that portion of electricity which seems necessary to the constitution of all terrestrial bodies, but it is liable also to be charged negatively or positively when electricity is abstracted or introduced by means of conducting bodies. These different states must occasion a variety of phenomena, and probably contribute considerably to the various combinations and decompositions continually going on in air. Professor Beccaria of Turin, found the air almost always positively electrical, especially in the day-time and in dry weather. When the dark or wet weather clears up, the electricity is always negative. Low thick fogs, rising into dry air, carry up a great deal of electric matter. In the morning, when the hygrometer indicates dryness equal to that of the preceding day, positive electricity obtains even before sunrise. As the sun gets up, this electricity increases more remarkably if the dryness increase. It diminishes in the evening. The mid-day electricity of days equally dry is proportional to the heat. Winds always lessen the electricity of a clear day, especially if damp. For the most part, when there is a clear sky with little wind, a considerable electricity arises after sunset at dew falling.

Air is not only electrified by friction, like other electric bodies, but the state of its electricity is changed by various chemical operations which often go on in the atmosphere. Evaporation seems in all cases to convey electric matter into the atmosphere. On the other hand, when steam is condensed into water, the air becomes negatively electric. Air, when heated, becomes negatively electric, and positively when cooled, even when it is not permitted to expand or contract: and the expansion and contraction of air also occasion changes in its electric state.

As air is an electric, the matter of electricity, when accumulated in any particular strata, will not immediately make its way to the neighbouring strata, but will induce in them changes similar to what is induced upon plates of glass or similar bodies piled upon each other. Therefore, if a stratum of air is electrified positively, the stratum immediately above it will be negative, the stratum above that positive, and so on. Suppose now, that an imperfect conductor were to come into contact with each of these strata; we know from the principles of electricity, that the equilibrium would be restored, and that this would be attended with a loud noise, and with a flash of light. Clouds are imperfect conductors: if a cloud, therefore, comes into contact with two such strata, a thunder-clap will follow. If a positive stratum is situated near the earth, the intervention of a cloud will, by serving as a stepping-stone, bring the stratum within the striking distance, and a thunder-clap will be heard while the electrical fluid is discharging itself into the earth. If the stratum is negative, the contrary effects will take place. It does not appear, however, that thunder is often occasioned by a discharge of electric matter from the earth into the atmosphere. The accidents, most of them at least, which were formerly ascribed to this cause, are now much more satisfactorily accounted for by Lord Stanhope's theory of the returning stroke. The discharge from the clouds directly into the earth is also probably less frequent than from cloud to cloud.

Some idea may be formed of the prodigious quantity of the electric fluid that is sometimes manifested, and passing between the clouds and the earth, by an instance or two with which we are furnished by M. De Luc. Thus a cloud was observed at the top of the mountains of Turin: it was formed of a mass, whose obscurity rendered it terrific, producing, in those places over which it was situated, night at noon day; this mass was ploughed as it were by lightning, which was soon after followed by a grumbling kind of thunder: there fell so prodigious a quantity of water and ice from this cloud, that the country was ravaged by the torrents, the hedges were beat down, and the ditches half filled with hail. Erfurt, a small city in Germany, was struck in one night in forty-two different places; seven persons were killed, and three houses were set on fire, but quenched by the rain, which came down in torrents.

It is not unusual for thunder-storms to produce most violent whirlwinds, such as are by some philosophers attributed to electricity; nay, even to occasion an agitation in the waters of the ocean itself; and all this too after the thunder and lightning have ceased. Of this the following instance happened at Great Malvern, October 16, 1761. At a quarter past four in the afternoon, the people were surprised with a most shocking and dismal noise; a hundred forges, all at work at once, could scarce equal it. Upon the side of the hill, about 400 yards to the SW. there appeared a prodigious smoke, attended with the same violent noise, as if a volcano had burst out of the hill; it soon descended, and passed on within about 100 yards of the south end of the house; it seemed to rise again in the meadow just below it, and continued its progress to the east, rising in the same manner for four different times, attended with the same dismal noise as at first; the air being filled with a nauseous and sulphureous smell. It gradually decreased till it was quite extinguished in a turnip-field, about a quarter of a mile below the house; the turnip-leaves, with leaves of trees, dirt, sticks, &c.

filled the air, and flew higher than any of the hills. The thunder ceased before this happened, and the air soon afterwards became calm and serene.

OF RAIN.

Mr. Luke Howard, who may be considered as our most accurate scientific meteorologist, is inclined to think, that rain is in almost every instance the result of the electrical action of clouds upon each other. This idea is confirmed by observations made in various ways upon the electrical state of clouds and rain; and it is very probable that a thunder-storm is only a more sudden and sensible display of those energies, which, according to the order observable in the creation in other respects, ought to be incessantly and silently operating for more general and beneficial purposes.

The excess, for any given time, of the falling water over that which is evaporated, passes off by the springs and rivers to that grand reservoir which forms the far greater part of the surface of the globe. Tracts of forest, especially if mountainous, invite the rain, and protect the springs; while the accumulated heat on cultivated plains often causes the clouds to pass over them, or to be dissipated.

The quantity of rain, taken at an annual mean, is the greatest at the equator, and it decreases gradually to the poles; but there are fewer days of rain there, the number of which increase in proportion to the distance from it. From north latitude 12 deg. to 43 deg. the mean number of rainy days is 78; from 43 deg. to 46 deg. the mean number is 103; from 46 deg. to 50 deg. 134; and from 51 deg. to 60 deg. 161. Winter often produces a greater number of rainy days than summer, though the quantity of rain is more considerable in the latter than in the former season. Mountainous districts are subject to great falls of rain; among the Andes particularly, it rains almost incessantly; while the flat country of Egypt is consumed by endless drought. The rain-gauge affords reason to suppose, that a greater quantity of rain falls in the lower strata of the atmosphere than in those above, which may be accounted for by the drops attracting vapour in their near approach to the earth. Mr. Copland, of Dumfries, has, however, discovered the rain collected in the lower gauge was greatest when it continued falling for some time, and that the greatest quantity was collected in the higher during short rains, or at the conclusion of lengthened ones.

As rain is known to fall at all hours of the day and night, and at every season of the year, it is apparent that it is caused by operations which prevail eternally, and without defined interruption. The mean annual quantity of rain for the whole globe has been calculated to be about 34 inches. The superficies of the globe consist of 170,981,012 square miles, or 686,401,498,471,475,200 square inches; the quantity of rain, therefore, falling annually, will amount to 23,337,650,812,030,156,800 cubic inches, or somewhat more than 91,751 cubic miles of water. There are 52,745,253 square miles of dry land on the globe; consequently the annual amount of the quantity of rain descending upon it will be 30,960 cubic miles.

The quantity of water running annually into the sea is 13,140 cubic miles; a quantity of water equal to which must be supplied by evaporation from the sea, otherwise the land would soon be completely drained of its moisture.

The quantity of rain falling annually in Great Britain may be seen from the following table: which is probably the most extensive of the kind; and as accurate as the use of instruments, not constructed by one person, and adjusted to a common standard, will allow. It is mostly compiled from the transactions of different learned societies.

COUNTIES (maritime).	PLACES.	Mean ann. depth in inches.
Cumberland.. ..	Keswick, 7 years	67. 5
	Carlisle, 1 year.. ..	20. 2
Westmoreland ..	Kendal, 11 years ..	59. 8
	Fell-foot, 3 years ..	55. 7
	Waith Sutton, 5 years	46

Counties (maritime).	Places.	Mean ann. depth in inches.
Lancashire	Lancaster, 10 years	45
	Liverpool, 18 years	34. 4
	Manchester, 9 years	33
	Townley	41
	Crawshawbooth, near Haslingdon, 2 years	60
Gloucestershire	Bristol, 3 years	29. 2
Somersetshire	Bridgewater, 3 years	29. 3
Cornwall	Ludguan, near Mount's Bay, 5 years	41
	Another place, 1 year	29. 9
Devonshire	Plymouth, 2 years	46. 5
Hampshire	Selbourne, 9 years	37. 2
	Fyfield, 7 years	25. 9
Kent	Dover, 5 years	37. 5
Essex	Upminster	19. 5
Norfolk	Norwich, 13 years	25. 5
Yorkshire	Barrowby, near Leeds, 6 yrs.	27. 5
	Garsdale, near Sedbergh, 3 years	52. 3
Northumberland	Widdrington, 1 year	21. 2

Counties (inland).	Places.	Means.
Middlesex	London, 7 years	23
Surrey	South Lambeth, 9 years	22. 7
Hertfordshire	Near Ware, 5 years	25
Huntingdonshire	Kimbolton, 7 years	25
Derbyshire	Chatsworth, 15 years	27. 8
Rutlandshire	Lyndon, 21 years	24. 3
Northamptonshire	Near Oundle, 14 years	23
	General mean	35. 2

As the places subject to much rain predominate considerably in this list, it will probably be nearer the truth, if we take the mean annual rain in England and Wales at a quantity not exceeding 32 inches.

In this country it generally rains less in March than in November, in the proportion, at a medium, of 7 to 12. It generally rains less in April than October, in the proportion of 1 to 2, nearly at a medium. It generally rains less in May than September; the chances that it does so are at least 4 to 3: but when it rains plentifully in May, (as 1.8 inches or more), it generally rains but little in September; and when it rains one inch or less in May, it rains plentifully in September.

OF SNOW.

Snow is formed by a process of regular crystallization among the minute frozen particles of water floating in the air. Previous to and during the fall of snow in quantity, the temperature continues about 32 deg. It should seem that the evolution of the constituent caloric of the water produces the same effect when ice is formed in the atmosphere, as when it is formed in water. The structure of a crystal of snow demonstrates that a drop of rain is also formed by the union of a great number of smaller drops. When these come together in the act of freezing, and suddenly, they form a nucleus of white spongy ice, which, by its extreme coldness, becoming incrusted with clear ice from the water it collects in its descent, constitutes hail as we usually see it. Sometimes, however, the nucleus falls unincrusted, which is a prognostic of sharp frosts. Hail has been likewise observed perfectly transparent, and having the form of an oblate spheroid, showing that it consisted of drops which had been frozen entire in falling with a rotary motion.

The forms assumed by the suspended water in the interval between the first precipitation and the descent of rain afford a copious field of observation. These are not, as might be hastily supposed, the sport of winds, changing with every movement of the containing medium. Indeed the atmosphere, at the height where the clouds usually appear, is undisturbed by the various obstacles which throw it into contending streams and eddies near the surface of the earth, and flows in a more direct and even current. Accordingly, the particles of water which it contains are allowed to assume a certain arrangement; and constitute a form, which is often equally well defined at a distance with that of solids, although, were we to penetrate it, we should perceive only the grey mist.

By the term cloud is meant a mass of vapour, more or less opaque, formed and sustained at considerable heights in the atmosphere, probably by the joint agencies of heat and electricity. The first successful attempt to arrange the diversified forms of clouds, under a few general modifications, was made by Luke Howard, Esq. We shall give here a brief account of his ingenious classification.

The *simple* modifications are thus named and defined: 1. *Cirrus.* Parallel, flexuous, or diverging fibres, extensible in any or in all directions. 2. *Cumulus.* Convex or conical heaps, increasing upwards from a horizontal base. 3. *Stratus.* A widely extended, continuous horizontal sheet, increasing from below.

The *intermediate* modifications which require to be noticed are, 4. *Cirro-cumulus.* Small well-defined roundish masses, in close horizontal arrangement. 5. *Cirro-stratus.* Horizontal, or slightly inclined masses, attenuated towards a part or the whole of their circumference, bent downward, or undulated, separate or in groups, consisting of small clouds having these characters.

The *compound* modifications are, 6. *Cumulo-stratus.* The cirro-stratus, blended with the cumulus, and either appearing intermixed with the heaps of the latter, or superadding a wide-spread structure to its base.

7. *Cumulo-cirro-stratus*, vel *Nimbus.* The rain cloud. A cloud or system of clouds from which rain is falling. It is a horizontal sheet, above which the cirrus spreads, while the cumulus enters it laterally and from beneath.

The *cirrus* appears to have the least density, the greatest elevation, the greatest variety of extent and direction, and to appear earliest on serene weather, being indicated by a few threads penciled on the sky. Before storms they appear lower and denser, and usually in the quarter opposite to that from which the storm arises. Steady high winds are also preceded and attended by *cirrus* streaks, running quite across the sky in the direction they blow in.

The cumulus has the densest structure, is formed in the lower atmosphere, and moves along with the current next the earth. A small irregular spot first appears, and is, as it were, the nucleus on which they increase. The lower surface continues irregularly plane, while the upper rises into conical or hemispherical heaps; which may afterwards continue long nearly of the same bulk, or rapidly rise into mountains. They will begin, in fair weather, to form some hours after sunrise, arrive at their maximum in the hottest part of the afternoon, then go on diminishing, and totally disperse about sunset. Previous to rain, the cumulus increases rapidly, appears lower in the atmosphere, and with its surface full of loose fleeces or protuberances. The formation of large cumuli to leeward in a strong wind indicates the approach of a calm with rain. When they do not disappear or subside about sunset, but continue to rise, thunder is to be expected in the night. The *stratus* has a mean degree of density, and is the lowest of clouds, its inferior surface commonly resting on the earth or water. This is properly the cloud of night appearing about sunset. It comprehends all those creeping mists, which in calm weather ascend in spreading sheets (like an inundation of water,) from the bottom of valleys, and the surfaces of lakes and rivers. On the return of the sun, the level surface of this cloud begins to put on the appearance of cumulus, the whole at the same time separating from the ground. The continuity is next destroyed, and the cloud ascends and evaporates, or passes off with the appearance of the nascent cumulus. This has long been experienced as a prognostic of fair weather.

The *cirrus* having continued for some time increasing or stationary, usually passes either to the cirro-cumulus or the cirro-stratus, at the same time descending to a lower station in the atmosphere. This modification forms a very beautiful sky; is frequent in summer, an attendant on warm and dry weather. The *cirro-stratus*, when seen in the distance, frequently gives the idea of shoals of fish. It precedes wind and rain; is seen in the intervals of storms; and sometimes alternates with the cirro-cumulus in the same cloud, when the different evolutions form a curious spectacle. A judgment may be formed of the weather likely to ensue by observing which modification prevails at last. The solar and lunar *halos*, as well as the parhelion and paraselene (mock sun and mock moon), prognostics of foul weather, are occasioned by this cloud. The cumulo-stratus precedes, and the nimbus accompanies rain.

OF DEW.

This meteorological phenomenon has of late particularly engaged the attention of philosophers. The first facts that could lead to the explanation of this hitherto little understood subject are due to the late Mr. A. Wilson, Professor of Astronomy in Glasgow, and his son.

Dr. Wilson had previously, in 1781, described the surface of snow, during a clear and calm night, to be 16° colder than air two feet above it; and in the above paper he shows, that the deposition of dew and hoar-frost is uniformly accompanied with the production of cold. He was the first among philosophical observers who noticed this conjunction. But the different force with which different surfaces project or radiate heat being then unknown, Dr. Wilson could not trace the phenomena of dew up to their ultimate source. This important contribution to science has been lately made by Dr. Wells, in his very ingenious and masterly Essay on Dew.

1. *Phenomena of Dew.*

Aristotle justly remarked, that dew appears only on calm and clear nights. Dr. Wells shows that very little is ever deposited in opposite circumstances; and *that little* only when the clouds are very high. It is never seen on nights both cloudy and windy; and if in the course of the night the weather, from being serene, should become dark and stormy, dew which had been deposited will disappear. In calm weather, if the sky be partially covered with clouds, more dew will appear than if it were entirely uncovered.

Dew probably begins in the country to appear upon grass, in places shaded from the sun, during clear and calm weather, soon after the heat of the atmosphere has declined, and continues to be deposited through the whole night, and for a little after sunrise. Its quantity will depend in some measure on the proportion of moisture in the atmosphere, and is consequently greater after rain than after a long tract of dry weather; and in Europe, with southerly and westerly winds, than with those that blow from the north and the east. The direction of the sea determines this relation of the winds to dew. For in Egypt, dew is scarcely ever observed except while the northerly or Etesian winds prevail. Hence also dew is generally more abundant in spring and autumn than in summer. And it is always very copious on those clear nights which are followed by misty mornings, which show the air to be loaded with moisture. And a clear morning, following a cloudy night, determines a plentiful deposition of the retained vapour. When warmth of atmosphere is compatible with clearness, as is the case in southern latitudes, though seldom in our country, the dew becomes much more copious, because the air then contains more moisture. Dew continues to form with increased copiousness as the night advances, from the increased refrigeration of the ground.

2. *On the Cause of Dew.*

Dew, according to Aristotle, is a species of rain, formed in the lower atmosphere, in consequence of its moisture being condensed by the cold of the night into minute drops. Opinions of this kind, says Dr. Wells, are still entertained by many persons, among whom is Professor Leslie. (*Relat. of Heat and Moisture*, pp. 37, and 132.) A fact, however, first taken notice of by Gerstin, who published his treatise on dew in 1773, proves them to be erroneous; for he found that bodies a little elevated in the air often become moist with dew, while similar bodies, lying on the ground, remain dry, though necessarily, from their position, *as* liable to be wetted, by whatever falls from the heavens, as the former.

After a long period of drought, when the air was very still and the sky serene, Dr. Wells exposed to the sky, 28 minutes before sunset, previously weighed parcels of wool and swandown, upon a smooth, unpainted, and perfectly dry fir table, 5 feet long, 3 broad, and nearly three in height, which had been placed, an hour before, in the sunshine in a large level grass-field. The wool, 12 minutes after sunset, was found to be 14° colder than the air, and to have acquired no weight. The swandown, the quantity of which was much greater than that of the wool, was at the same time 13° colder than the air, and was also without any additional weight. In 20 minutes more, the swandown was 14½° colder than the neighbouring air, and was still without any increase of its weight. At the same time the grass was 15° colder than the air four feet above the ground.

Dr. Wells, by a copious induction of facts, derived from observation and experiment, establishes this proposition, *that bodies become colder than the neighbouring air* BEFORE *they are dewed.* The cold therefore which Dr. Wilson and Mr. Six conjectured to be the effect of dew, now appears to be its cause. But what makes the terrestrial surface colder than the atmosphere? The radiation or projection of heat into free space. Now the researches of Professor Leslie and Count Rumford have demonstrated, that different bodies project heat with very different degrees of force.

In the operation of this principle, therefore, conjoined with the power of a concave mirror of cloud, or any other awning, to reflect or throw down again those calorific emanations which would be dissipated in a clear sky, we shall find a solution of the most mysterious phenomena of dew. Two circumstances must here be considered:—

1. The exposure of the particular surface to be dewed, to the free aspect of the sky.

2. The peculiar radiating power of the surface. 1.

Whatever diminishes the view of the sky, as seen from the exposed body, obstructs the depression of its temperature, and occasions the quantity of dew formed upon it to be less than would have occurred, if the exposure to the sky had been complete.

Dr. Wells bent a sheet of pasteboard into the shape of a penthouse, making the angle of flexure 90 degrees, and leaving both ends open. This was placed one evening with its ridge uppermost, upon a grass-plat in the direction of the wind, as well as this could be ascertained. He then laid 10 grains of white and moderately fine wool, not artificially dried, on the middle part of that spot of the grass which was sheltered by the roof, and the same quantity on another part of the grass-plat, fully exposed to the sky. In the morning the sheltered wool was found to have increased in weight only 2 grains, but that which had been exposed to the sky 16 grains. He varied the experiment on the same night, by placing upright on the grass-plat a hollow cylinder of baked clay, 1 foot diameter, and 2½ feet high. On the grass round the outer edge of the cylinder were laid 10 grains of wool, which in this situation, as there was not the least wind, would have received as much rain as a like quantity of wool fully exposed to the sky. But the quantity of moisture acquired by the wool partially screened by the cylinder from the *aspect* of the sky was only about 2 grains, while that acquired by the same quantity fully exposed was 16 grains. Repose of a body seems necessary to its acquiring its utmost coolness, and a full deposit of dew. Gravel walks and pavements project heat, and acquire dew, less readily than a grassy surface. Hence wool placed on the former has its temperature less depressed than on the latter, and therefore is less bedewed. Nor does the wool here attract moisture by capillary action on the grass, for the same effect happens if it be placed in a saucer. Nor is it by hydrometric attraction; for in a cloudy night, wool placed on an elevated board acquired scarcely any increase of weight.

If wool be insulated a few feet from the ground on a bad conductor of heat, as a board, it will become still colder than when in contact with the earth, and acquire fully more dew than on the grass. Glass projects heat rapidly, and is as rapidly coated with dew. But bright metals attract dew much less powerfully than other bodies. If we coat a piece of glass, partially, with bright tin-foil, or silver leaf, the uncovered portion of the glass quickly becomes cold by radiation, on exposure to a clear nocturnal sky, and acquires moisture; which, beginning on those parts most remote from the metal, gradually approaches it. Gold, silver, copper, and tin, bad radiators of heat, and excellent conductors, acquire dew with greater difficulty than platina, which is a more imperfect conductor; or than lead, zinc, and steel, which are better radiators. Hence dew which was formed upon a metal will often disappear, while other substances in the neighbourhood remain wet; and a metal, purposely moistened, will become dry, while neighbouring bodies are acquiring moisture. This repulsion of dew is communicated by metals to bodies in contact with, or near them. Wool laid on metal acquires less dew than wool laid on the contiguous grass.

When, during a clear and still night, different thermometers, placed in different situations, were examined at the same time, those which were situated where most dew was formed were always found to be the lowest. On dewy nights the temperature of the earth, half an inch or an inch beneath the surface, is always found much warmer than the grass upon it, or the air above it. The differences on five such nights were from 12 to 16 degrees.

In making experiments with thermometers, it is necessary to coat their bulbs with silver or gold leaf, otherwise the glassy surface indicates a lower temperature than that of the air, or the metallic plate it touches. Insulated bodies, or prominent points, are sooner covered with hoar-frost and dew than others; because the equilibrium of their temperature is more difficult to be restored. As aerial stillness is necessary to the cooling effect of radiation, we can understand why the hurtful effects of cold, heavy fogs, and dews, occur chiefly in hollow and confined places, and less frequently on hills. In like manner, the leaves of trees often remain dry throughout the night, while the blades of grass are covered with dew.

No direct experiments can be made to ascertain the manner in which clouds prevent or lessen the appearance of a cold at night, upon the surface of the earth, greater than that of the atmosphere. But it may be concluded from the preceding observations, that they produce this effect almost entirely by radiating heat to the earth, in return for that which they intercept in its progress from the earth towards the heavens. The heat extricated by the condensation of transparent vapour into cloud must soon be dissipated; whereas, the effect of greatly lessening, or preventing altogether, the appearance of a greater cold on the earth than that of the air, will be produced by a cloudy sky during the whole of a long night.

We can thus explain, in a more satisfactory manner than has usually been done, the sudden warmth that is felt in winter, when a fleece of clouds supervenes in clear frosty weather. Chemists ascribed this sudden and powerful change to the disengagement of the latent heat of the condensed vapours; but Dr. Wells's thermometric observations on the sudden alternations of temperature by cloud and clearness render that opinion untenable. We find the atmosphere itself, indeed, at moderate elevations, of pretty uniform temperature, while bodies at the surface of the ground suffer great variations in *their* temperature.

This single fact is fatal to the hypothesis derived from the doctrines of latent heat.—" I had often," says Dr. Wells, " smiled, in the pride of half knowledge, at the means frequently employed by gardeners to protect tender plants from cold, as it appeared to me impossible that a thin mat, or any such flimsy substance, could prevent them from attaining the temperature of the atmosphere, by which alone I thought them liable to be injured. But when I had learned, that bodies on the surface of the earth become, during a still and serene night, colder than the atmosphere, by radiating their heat to the heavens, I perceived immediately a just reason for the practice which I had before deemed useless. Being desirous, however, of acquiring some precise information on this subject, I fixed, perpendicularly, in the earth of a grass-plat four small sticks, and over their upper extrêmities, which were six inches above the grass, and formed the corners of a square whose sides were two feet long, I drew tightly a very thin cambric handkerchief. In this disposition of things, therefore, nothing existed to prevent the free passage of air from the exposed grass to that which was sheltered, except the four small sticks, and there was no substance to radiate downwards to the latter grass, except the cambric handkerchief."

The sheltered grass, however, was found nearly of the same temperature as the air, while the unsheltered was 5° or more colder. 'One night the fully exposed grass was 11° colder than the air; but the sheltered grass was only 3° colder. Hence we see the power of a very slight awning, to avert or lessen the injurious coldness of the ground. To have the full advantage of such protection from the chill aspect of the sky, the covering should not touch the subjacent bodies. Garden walls act partly on the same principle. Snow screens plants from this chilling radiation.

From this rapid emission of heat from the surface of the ground, we can now explain the formation of ice during the night in Bengal, while the temperature of the air is above 32°. The nights most favourable for this effect are those which are the calmest and most serene, and on which the air is so dry as to deposit little dew after midnight. Clouds and frequent changes of wind are certain preventives of congelation. Three hundred persons are employed in this operation at one place. The enclosures formed on the ground are four or five feet wide, and have walls only four inches high. In these enclosures, previously bedded with *dry* straw, broad, shallow, unglazed earthen pans are set, containing *unboiled pump-water*. Wind, which so greatly promotes evaporation, prevents the freezing altogether, and dew forms in a greater or less degree during the whole of the nights most productive of ice. If evaporation were concerned in the congelation, wetting the straw would promote it. Moist straw both conducts heat and raises vapour from the ground, so as to obstruct the congelation.

The preceding may be considered as the chief of what may be termed the common phenomena of Meteorology; there are others, however, which may be denominated *remarkable* phenomena, and which, though some modern writers on the subject have discarded them, deserve to be noticed here, and which, in our opinion, do most strictly belong to the science. In briefly noticing these, we shall divide them into *Igneous* and *Aqueous* meteors.

IGNEOUS METEORS.

These may be reduced into three classes, viz. fireballs, falling or shooting stars, and ignes fatui.

Those phenomena which are classed together under the general appellation of fire-balls were divided by the ancients into several species, according to the external form or appearance which they assumed. In tropical climates these meteors are more common and more stupendous than in these more temperate regions.

Two meteors appeared in England in the year 1783, of which a most particular account and ingenious solution, by Dr. Blagden, are published in the Philosophical Transactions of the following year. The first of these was seen on the 18th of August, and was, in appearance, a luminous ball, which rose in the N. N. W, nearly round: it, however, soon became elliptical, and gradually assumed a tail as it ascended, and in a certain part of its course seemed to undergo a remarkable change, compared to bursting; after which it proceeded no longer as an entire mass, but was apparently divided into a cluster of balls of different magnitudes, and all carrying or leaving a train behind, till, having passed the east, and verging considerably to the south, it gradually descended, and was lost out of sight. The time of its appearance was about sixteen minutes past nine in the evening, and it was visible about half a minute.

It was seen in all parts of Great Britain, at Paris, at Nuits in Burgundy, and even at Rome; and is supposed to have described a tract of 1000 miles at least over the surface of the earth. The illumination of these meteors is often so great as totally to obliterate the stars, to make the moon look dull, and even to affect the spectators like the sun itself. The body of the fire-ball, even before it burst, did not appear of a uniform brightness, but consisted of lucid and dull parts, which were constantly changing their respective positions, so that the whole effect was to some eyes like an internal agitation or boiling of the matter. By the best accounts that could be procured concerning the height of the meteor, it seems to have varied from 55 to 60 miles. A report was heard some time after the meteor disappeared, and this report was loudest in Lincolnshire and the adjacent parts, and again in the eastern parts of Kent. Judging from the height of the meteor, its bulk is conjectured to have been not less than half a mile in diameter; and when we consider this bulk, its velocity cannot fail to astonish us, which is supposed to be at the rate of more than 40 miles in a second.

It seems to be the opinion of Dr. Blagden and others, that the general cause of these phenomena is electricity; but notwithstanding the ingenious arguments urged in defence of this hypothesis, we still entertain considerable doubts as to its correctness. The duration of the fire-ball, the unequal consistency of the mass, and several other points in the narration, seem to indicate that its materials were of a less rare and evanescent nature than the electric matter.

The shooting or falling-star is a common phenomenon; but though so frequently observed, the great distance and transient nature of these meteors have hitherto frustrated every attempt to ascertain their cause. The connexion of these with an active state of the atmospheric electricity is however certain, from observation; and we have more reason to consider them as electric scintillæ than as solid or fluid matter in the act of combustion. They precede a change of wind.

Concerning the nature and composition of the *ignis fatuus*, or Will-with-a-wisp, there is less dispute; the generality of philosophers being agreed, that it is caused by some volatile vapour of the phosphoric kind, probably the phosphorized hydrogen gas. The light from putrescent substances, particularly putrid fish, and those sparks emitted from the sea, or sea-water when agitated, in the dark, correspond in appearance with this meteor. Sir Isaac Newton defines the ignis fatuus to be "a vapour shining without heat;" and it is usually visible in damp places, about dunghills, burying-grounds, and other situations which are likely to abound with phosphoric matter.

These meteors are very common in Italy and in Spain: Dr. Shaw has described a remarkable Ignis Fatuus, which he saw in the Holy Land, when the atmosphere was so uncommonly thick and hazy, that the dew on the horses' bridles was remarkably clammy and unctuous. This meteor was sometimes globular, then in the form of the flame of a candle, presently afterwards it spread itself so much as to involve the whole company in a pale harmless light, and then it would contract itself again, and suddenly disappear; but, in less than a minute, it would become visible as before, and running along from one place to another, with a swift progressive motion, would again expand itself, and cover a considerable space of ground.

AQUEOUS METEORS.

Among the numerous aqueous meteors that have been noticed by philosophical writers, the following are the principal. First, what is commonly called.

The Spectre of the Broken.

This name is given to an aëriel figure sometimes seen on the Hartz mountains in Hanover, and no doubt is produced by the aqueous particles that float in the air. The following account is taken from M. Haue's description of this meteor.

"Having ascended the Broken (mountain) for the thirtieth time, I was at length so fortunate as to have the pleasure of seeing this phenomenon. The sun rose about four o'clock, and the atmosphere being quite serene towards the east, its rays could pass without any obstruction over the Heinrichshöhe mountain. In the south-west, however, towards the mountain Achtermannshöhe, a brisk west wind carried before it thin transparent vapours. About a quarter past four I looked round, to see whether the atmosphere would permit me to have a free prospect to the south-west, when I observed, at a very great distance towards the Achtermannshöhe, a human figure of a monstrous size! A violent gust of wind having almost carried away my hat, I clapped my hand to it; and in moving my arm towards my head, the colossal figure did the same.

"The pleasure which I felt at this discovery can hardly be described; for I had already walked many a weary step in the hope of seeing this shadowy image, without being able to gratify my curiosity. I immediately made another movement, by bending my body, and the colossal figure before me repeated it. I was desirous of doing the same thing once more, but my colossus had vanished. I remained in the same position, waiting to see whether it would return; and in a few minutes it again made its appearance on the Achtermannshöhe. I then called the landlord of the neighbouring inn, and having both taken the position which I had taken alone, we looked towards the Achtermannshöhe, but did not perceive any thing. We had not, however, stood long, when two such colossal figures were formed over the above eminence, which repeated their compliments by bending their bodies as we did, after which they vanished. We retained our position, kept our eyes fixed on the spot, and in a little time the two figures again stood before us, and were joined by a third:" [that of a traveller who then came up and joined the party.] "Every movement made by us, these figures imitated; but with this difference, that the phenomenon was sometimes weak and faint, sometimes strong and well defined."

Of the Fata Morgana.

This is a very remarkable aerial phenomenon, which is sometimes observed from the harbour of Messina and adjacent places, at a certain height in the atmosphere. The name, which signifies the Fairy Morgana, is derived from an opinion of the superstitious Sicilians, that the whole spectacle is produced by fairies, or such-like visionary invisible beings. The populace are delighted whenever it appears; and run about the streets shouting for joy, calling every body out to partake of the glorious sight.

This singular meteor has been described by various authors; but the first who mentioned it with any degree of precision was father Angelucci, whose account is thus quoted by Mr. Swinburne in his Tour through Sicily: "On the 15th of August, 1643, as I stood at my window, I was surprised with a most wonderful delectable vision. The sea that washes the Sicilian shore swelled up, and became, for ten miles in length, like a chain of dark mountains; while the waters near our Calabrian coast grew quite smooth, and in an instant appeared as one clear polished mirror, reclining against the ridge. On this glass was depicted in chiaro-scuro a string of several thousand of pilasters, all equal in altitude, distance, and degree of light and shade. In a moment they lost half their height, and bent into arcades, like Roman aqueducts. A long cornice was next formed on the top, and above it rose castles innumerable, all perfectly alike. These soon split into towers, which were shortly after lost in colonnades, then windows, and at last ended in pines, cypresses, and other trees, even and similar." This is the Fata Morgana, which for twenty-six years I had thought a mere fable."

To produce this pleasing deception, many circumstances must concur, which are not known to exist in any other situation. The spectator must stand with his back to the east, in some elevated place behind the city, that he may command a view of the whole bay; beyond which the mountains of Messina rise like a wall, and darken the back ground of the picture. The winds must be hushed, the surface quite smooth, the tide at its height, and the waters pressed up by currents to a great elevation in the middle of the channel. All these events coinciding, as soon as the sun surmounts the eastern hills behind Reggio, and rises high enough to form an angle of 45 degrees on the water before the city, every object existing or moving at Reggio will be repeated a thousand-fold upon this marine looking-glass; which, by its tremulous motion, is in a manner cut into facets. Each image will pass rapidly off in succession as the day advances, and the stream carries down the wave on which it appeared. Thus the parts of this moving picture will vanish in the twinkling of an eye. Sometimes the air is at that moment so impregnated with vapours, and undisturbed by winds, as to reflect objects in a kind of aerial screen, rising about 30 feet above the level of the sea. In cloudy heavy weather they are drawn on the surface of the water, bordered with fine prismatical colours.

Of Water-spouts.

A water-spout is an extraordinary aqueous meteor, most frequently observed at sea. It is a truly formidable phenomenon, and is indeed capable of causing great ravages. It commonly begins by a cloud, which appears very small, and which mariners call the squall; which augments in a little time into an enormous cloud of a cylindrical form, or that of a reversed cone, and produces a noise like an agitated sea, sometimes emitting thunder and lightning, and also large quantities of rain or hail, sufficient to inundate large vessels, overset trees and houses, and every thing which opposes its violent impetuosity.

These water-spouts are more frequent at sea than by land; and sailors are so convinced of their dangerous consequences, that when they perceive their approach, they frequently endeavour to break them by firing a cannon before they approach too near the ship. They have also been known to commit great devastations by land; though, where there is no water near, they generally assume the harmless form of a whirlwind. To enable the reader to understand their nature, we shall preface the different theories by a short description of one of these wonderful appearances, as given by the celebrated M. Tournefort, in his Voyage to the Levant.

"The first of these," says this traveller, "that we saw, was about a musket-shot from our ship. There we perceived the water began to boil, and to rise about a foot above its level. The water was agitated and whitish; and above its surface there seemed to stand a smoke, such as might be imagined to come from wet straw before it begins to blaze. It made a sort of a murmuring sound, like that of a torrent heard at a distance, mixed at the same time with a hissing noise, like that of a serpent: shortly after, we perceived a column of this smoke rise up to the clouds, at the same time whirling about with great rapidity. It appeared to be as thick as one's finger; and the former sound still continued. When this disappeared, after lasting for about eight minutes, upon turning to the opposite quarter of the sky, we perceived another, which began in the manner of the former; presently after a third appeared in the west; and instantly beside it still another arose. The most distant of these three could not be above a musket-shot from the ship. They all continued like so many heaps of wet straw set on fire, that continued to smoke, and to make the same noise as before. We soon after perceived each, with its respective canal, mounting up in the clouds; and spreading, where it touched the cloud, like the mouth of a trumpet; making a figure, to express it intelligibly, as if the tail of an animal was pulled at one end by a weight. These canals were of a whitish colour, and so tinged, as I suppose, by the water which was contained in them; for, previous to this, they were apparently empty, and of the colour of transparent glass. These canals were not straight, but bent in some parts, and far from being perpendicular, but rising in their clouds with a very inclined ascent. But what is very particular, the cloud to which one of them was pointed happening to be driven by the wind, the spout still continued to follow its motion, without being broken; and passing behind one of the others, the spouts crossed each other, in the form of a St.

Andrew's cross. In the beginning, they were all about as thick as one's finger, except at the top, where they were broader, and two of them disappeared; but shortly after the last of the three increased considerably, and its canal, which was at first so small, soon became as thick as a man's arm, then as his leg, and at last thicker than his whole body. We saw distinctly, through this transparent body, the water, which rose up with a kind of spiral motion; and it sometimes diminished a little of its thickness, and again resumed the same; sometimes widening at top, and sometimes at bottom; exactly resembling a gut filled with water, pressed with the fingers, to make the fluid rise or fall; and I am well convinced that this alteration in the spout was caused by the wind, which pressed the cloud, and compelled it to give up its contents. After some time, its bulk was so diminished as to be no thicker than a man's arm again; and thus swelling and diminishing, it at last became very small. In the end, I observed the sea, which was raised about it, to resume its level by degrees, and the end of the canal that touched it to become as small as if it had been tied round with a cord; and this continued till the light, striking through the cloud, took away the view. I still, however, continued to look, expecting that its parts would join again, as I had before seen in one of the others, in which the spout was more than once broken, and yet again came together; but I was disappointed, for the spout appeared no more."

Whirlwinds and water-spouts are by the majority of philosophers referred to the same origin, but some have endeavoured to account for them on electrical principles. They observe that the effluent matter proceeds from a body actually electrified towards one which is not so; and the affluent matter proceeds from a body not electrified towards one which is actually so. These two currents occasion two motions analogous to the electrical attraction and repulsion.

If the current of the effluent matter is more powerful than the affluent matter, which in this case is composed of particles exhaled from the earth, the particles of vapours which compose the cloud are attracted by this effluent matter, and form the cylindrical column, called the descending water-spout; if, on the contrary, the affluent matter is the strongest, it attracts a sufficient quantity of aqueous particles to form gradually into a cloud, and this is commonly termed the ascending water-spout. It is farther observed of water-spouts, that the convergence of winds, and their consequent whirling motion, was a principal cause in producing that effect; but there are appearances which can hardly be solved by supposing that to be the only cause. They often vanish, and presently appear again in the same place: whitish or yellowish flames have sometimes been seen moving with prodigious swiftness about them, and whirlwinds are observed to electrify the apparatus very strongly. The time of their appearance is generally those months which are peculiarly subject to thunder-storms; and they are commonly preceded, accompanied, or followed, by lightning, the previous state of the air being alike in both cases. And the long-established custom which the sailors have of presenting sharp swords to disperse them, is no inconsiderable circumstance in favour of the supposition of their being electrical phenomena. Perhaps the ascending motion of the air, by which the whirling is produced, may be the current known to issue from electrified points, as the form of the protuberance in the sea is somewhat pointed, and the electrified drop of water may afford considerable light in explaining this appearance.

A different theory is, however, adopted by other respectable philosophers; and it is possible, after all, that there may really be two kinds of water-spouts, the one the effect of the electrical attraction, as noticed above, and the other caused by a vacuum, or extreme and sudden rarefaction of the air.

It is well known that even a common fire produces a kind of circulation of the air in a room, but in a different form. It is therefore not difficult to conceive, that when any part of the column of air upon the surface of the earth or water is suddenly rarefied, either by electricity or any other cause, a vacuum, at least comparatively to the rest of the air, will immediately take place, and the circumambient air rushing in at once from every quarter to fill the void, a conflict of winds ensues, and consequently a circular motion, by which light bodies will be taken up and turned round with considerable velocity; this violent rushing of the air on all sides into the vacuum then forms what is commonly called at land a whirlwind.

When this vacuum takes place at sea, from the nature of fluids, the water will rise to a certain height by the pressure of the atmosphere, as in a common pump; but as the vacuum is not quite perfect, the water will be divided into drops; and as these vacuums are generally caused by heat, it will be rarefied when it reaches the upper regions of the atmosphere, and assume the appearance of a cloud.

Mr. Oliver, whose theory is here adopted with little variation, illustrates the phenomenon by a very easy experiment. In a stiff paper card he made a hole just large enough to insert a goose quill; after cutting the quill off square at both ends, he laid the card upon the mouth of a wine glass, filled with water to within a fifth or sixth part of an inch from the low orifice of the quill; then applying his mouth to the upper part, he drew the air out of the quill, and in one draught of his breath drew in about a spoonful of water; and this he was able to repeat, the quill remaining as before. The water, he adds, did not ascend to his mouth in a stream, as it would have done had the quill reached the water, but broken, and confusedly mixed with the air which ascended with it. The usual phenomena of water-spouts are exactly agreeable to this theory. They appear at a distance like an inverted cone, or the point of a sword, which is owing to the water rising in large drops at the first, and being expanded as it ascends; and a cloud is generally suspended over the body of the phenomenon. The water which is taken up is undoubtedly salt at the first, but by the rarefaction in the superior regions it undergoes a kind of natural distillation, and loses all the heavy saline particles with which it was charged.

Water-spouts have been observed at land, of which two very remarkable instances are recorded in the

Philosophical Transactions. Other phenomena have been remarked, which can be explained upon these principles only. Accounts have been given of red and yellow rain, of frogs and tadpoles, and even of small fishes; having been rained upon the tops of houses. The red and yellow rain was probably composed of the blossoms of vegetables, or of insects, taken up by one of these aerial tubes; and the frogs and fishes were probably part of the contents of some pond, in which the water-spout originated, or over which it might have passed in its perambulation.

The point or cone of the water-spout is generally oblique, depending on the force and direction of the wind which drives it along.

OF METEORIC STONES.

Almost all the larger fire-balls have been observed to disappear with a loud explosion; and it was almost constantly affirmed that heavy stony bodies fell from them. But though several well-authenticated accounts of the fall of such stones had been from time to time published, little credit was given tc them by philosophers, till Dr. Chladni published a dissertation on the subject in 1794. Two years after, Mr. King published a still more complete collection of examples, many of them supported by such evidence that it was impossible to reject it. Mr. Howard having procured specimens of the stones which were said to have fallen in different places, compared them together, and subjected them to a chemical analysis. The result was, that all these stony bodies differ completely from every other known stone; that they all resemble each other; and that they are all composed of the same ingredients. They are found entirely different from all known stones, and exactly resemble each other, even in their component parts. They are heated and luminous when they reach the earth: the force of their descent buries them some depth into it; and they have been seen under these circumstances in Italy, Germany, France, England, and India. The meteors either really do, or appear to, move horizontally, and are said to descend ere they explode. The stones are of different sizes, and from a few ounces in weight to several tons; they are generally circular; and invariably covered with a rough black crust, which, according to Howard, is principally composed of oxide of iron. The stones which fell at Laigle, in France, in 1803, yielded by the analysis of Vauquelin and Fourcroy 54 parts silica, 36 oxide of iron, 19 magnesia, 5 oxide of nickel, 2 sulphur, and 1 lime:—and Mr. Howard found that 150 grains of a meteoric stone which fell in Yorkshire contained 75 silica, 37 magnesia, 48 oxide of iron, 2 oxide of nickel. The oxidizement of the metallic bodies caused this increase of weight.

Various conjectures have been formed as to the origin of these stones; some, with Laplace, supposing them to be ejected by volcanoes in the moon; and others, with Sir W. Hamilton and Mr. King, that they are concretions formed in the atmosphere.

Mr. Leslie is of opinion that they are fragments thrown off from the recently discovered planets, and precipitated to the earth by discharges of the electric fluid.

OF METEOROLOGICAL INSTRUMENTS.

There are now various instruments constructed by the philosophical instrument-makers for the use of those who make meteorology a study; a few of these we shall briefly notice.

The most common, and, doubtless, the most useful of these are the Barometer, and the Thermometer.

The Barometer.

This instrument, known amongst the vulgar by the name of *weather-glass*, plate XVII. fig. 1. is a cylindrical glass tube, whose diameter is generally about ⅓d or ¼th of an inch, and its length 34 inches, filled with prepared mercury: one end of the tube, A, is hermetically sealed, and the open end, B, inserted into a basin of mercury. The tube and basin are fixed to a frame of wood, and suspended in a vertical situation.

The height of the mercury in the tube above the surface of the mercury in the basin is called the standard altitude, and the difference between the greatest and least altitudes is called the limit or scale of variation.

The mercury in the barometer tube will subside, till the column be equivalent to the weight of the external air upon the surface of the mercury in the basin, and it is therefore a criterion to measure that weight, and chiefly directed to that purpose. In this kingdom the standard altitude fluctuates between 28 and 31 inches; and from hence it is justly inferred, that the greatest, least, and intermediate weights of the atmosphere upon a given base are respectively equal to the weights of columns of mercury upon the same base, whose vertical altitudes are 28, 31 inches, and some altitude contained between them.

The standard altitude ought to be the same, whatever be the diameter of the barometer tube; but when this diameter is very small, the attraction of cohesion between the mercury and glass prevents a variation of altitude, which ought to be, and in larger tubes is, sensible from small differences in the weight of the atmosphere.

There are other forms of the barometer, such as the diagonal, the portable, the mountain, the horizontal, and the pendant barometer, but of all these none is in such common use as the wheel barometer: the mode of fitting it up gives it an elegant appearance as a piece of furniture. It is represented by Fig. 2. and consists of a compound tube, S E R B D, open at D, and closed at E, the diameter of the highest part, S E R, being much greater than that of the rest, and filled with mercury from D to S R, and above that vacuous. Upon the surface of the mercury in the recurved leg there is an iron ball in equilibrio with another, H, by a string passing over a pulley P. As the ball at D rises and falls with the mercury, the string turns the pulley, and an index, I N, fixed to it, which points to different parts of a graduated circle. It is clear, that by increasing the diameter of the circle, this contrivance will show the minutest variations of the air, provided the friction be inconsiderable, which is seldom the case.

The Thermometer.

The thermometer is an instrument for measuring heat, founded on the principle, that the expansions of matter are proportional to the augmentations of temperature. A common thermometer, therefore, is merely a vessel in which very minute expansions of mercury may be rendered perceptible; and, by certain rules of graduation, be compared with expansions made on the same liquid by other observers.

Air is the most expansible fluid, but it does not receive nor part with its heat so quickly as mercury. Alcohol does not expand much by heat. In its ordinary state it does not bear a much greater heat than 175° of Fahrenheit; but when highly rectified it can bear a greater degree of cold than any other liquor hitherto employed as a measure of temperature. At Hudson's Bay, Mr. Macnab, by a mixture of vitriolic acid and snow, made it to descend to 69° below 0 of Fahrenheit. There is an inconvenience, however, attending the use of this liquor; it is not possible to get it always of the same degree of strength. As to oil, its expansion is about 15 times greater than that of alcohol; it sustains a heat of 600°, and its freezing point is so low that it has not been determined; but its viscosity renders it useless.

Mercury is far superior to alcohol and oil, and is much more manageable than air. 1. As far as the experiments already made can determine, it is of all the fluids hitherto employed in the construction of thermometers, that which measures most exactly equal differences of heat by equal differences of its bulk; its dilatations are, in fact, very nearly proportional to the augmentations of heat applied to it. 2. Of all liquids it is the most easily freed from air. 3. It is fitted to measure high degrees of heat and cold. It sustains a heat of 600° of Fahrenheit's scale, and does not congeal till it fall 39 or 40 degrees below 0. 4. It is the most sensible of any fluid to heat and cold, even air not excepted. Count Rumford found, that mercury was heated from the freezing to the boiling point in 58 seconds, while water took two minutes 13 seconds, and common air 10 minutes and 17 seconds. 5. Mercury is a homogeneous fluid, and every portion of it is equally dilated or contracted by equal variations of heat. Any one thermometer, made of pure mercury, is, *cæteris paribus*, possessed of the same properties with every other thermometer made of pure mercury.

Its power of expansion is indeed about six times less than that of spirit of wine, but it is great enough to answer most of the purposes for which a thermometer is wanted. The fixed points, which are now universally chosen for adjusting thermometers to a scale, and to one another, are the boiling and freezing water points. In order to ensure uniformity, therefore, in the construction of thermometers, it is now agreed, that the bulb of the tube be plunged in the water when it boils violently, the barometer standing at 30 English inches, and the temperature of the atmosphere 55 degrees.

As artists may be often obliged to adjust thermometers under very different pressures of the atmosphere, philosophers have been at pains to discover a general rule which might be applied on all occasions.

1. To convert the degrees of Reaumur into those of Fahrenheit; $\frac{R \times 9}{4} + 32 = F$.

2. To convert the degrees of Fahrenheit into those of Reaumur; $\frac{(F - 32) \times 4}{9} = R$.

To such readers as are unacquainted with the algebraic expression of arithmetical formulæ, it will be sufficient to express one or two of these in words to explain their use: 1. Multiply the degree of Reaumur by 9, divide the product by 4, and to the quotient add 32, the sum expresses the degree of the scale of Fahrenheit. 2. From the degree of Fahrenheit subtract 32, multiply the remainder by 4, and divide the product by nine; the quotient is the degree according to the scale of Reaumur, &c.

Thermometers have been made of a great variety of shapes and sizes.

The most common form is represented by Fig. 3. This figure shows merely the tube and index-plate; these are fitted up in cases of various kinds, according to the purpose for which they are wanted.

The common contrivance for a self-registering thermometer, now sold by the instrument-makers, consists simply of two thermometers, one mercurial, and the other of alcohol, Fig. 4, having their stems horizontal; the former has for its index a small bit of magnetical steel wire, and the latter a minute thread of glass, having its two ends formed into small knobs, by fusion in the flame of a candle.

The magnetical bit of wire lies in the vacant space of the mercurial thermometer, and is pushed forward by the mercury whenever the temperature rises, and pushes that fluid against it; but when the temperature falls, and the fluid retires, this index is left behind, and consequently shows the maximum. The other index, or bit of glass, lies in the tube of the spirit thermometer immersed in the alcohol; and when the spirit retires, by depression of temperature, the index is carried along with it, in apparent contact with its interior surface; but, on increase of temperature, the spirit goes forward and leaves the index, which, therefore, shows the minimum of temperature since it was set. As these indices merely lie in the tubes, their resistance to motion is altogether inconsiderable. The steel index is brought to the mercury by applying a magnet on the outside of the tube, and the other is duly placed at the end of the column of alcohol, by inclining the whole instrument.

The Hygrometer.

The air is not only susceptible of acquiring more or less heat, but also of becoming more or less humid. It belongs, therefore, to philosophy, to measure this degree of moisture; especially as this quality of the air has a great influence on the human body, on vegetation, and many other effects of nature.

This gave rise to the invention of the hygrometer, an instrument proper for measuring the humidity of the air.

But it must be allowed, that the instruments hitherto invented for this purpose do not give that result which might have been expected. We have hygrometers, indeed, which indicate that the air has acquired more or less moisture than it had before; but they are not comparative, that is to say, they do not enable us to compare the moisture of one day or place with that of another.

A very simple hygrometer, but subject to the above objections in a high degree, may be constructed with the beard of a wild oat, fixed on a small column, placed in the centre of a round box: the other extremity of the beard passes through the centre of the cover of the box, the circumference of which is divided into equal parts; in the last place a small index, made of paper, is adapted to the extremity of the beard. In order to afford access to the air, it is necessary that the sides of the box should be open, or cut into holes.

When this instrument is exposed to drier or moister air, the small index, by turning round, either in the one direction or the other, indicates the state of the atmosphere.

The first improvement, of any importance, in the construction of the hygrometer, belongs to M. de Luc of Geneva. Since his improvement has appeared it has again been improved on; and at present it is a point of dispute in the scientific world, whether the hygrometer of Leslie, or that of Daniell, be entitled to superiority. Without pretending to settle this point, we shall here subjoin a brief description of Mr. Daniell's hygrometer, represented by Fig. 5. A and B are two thin glass balls of an inch and a quarter diameter, connected together by a tube, having a bore of about an eighth of an inch. The tube is bent at right angles, over the two balls, and the arm *b c* contains a small thermometer D, whose bulb, which should be of a lengthened form, descends into the ball B. This ball having been about two-thirds filled with ether, is heated over a lamp till the fluid boils, and the vapour issues from the capillary tube F, which terminates the ball *a*. The vapour having expelled the air from both balls, the capillary tube F is hermetically closed by the flame of a lamp. This process is familiar to those who are accustomed to blow glass, and may be known to have succeeded after the tube has become cool, by reversing the instrument, and taking one of the balls in the hand, the heat of which will drive all the ether into the other ball, and cause it to boil rapidly. The other ball *a* is now to be covered with a piece of muslin. The stand G H is of brass, and the transverse socket I is made to hold the glass tube in the manner of a spring, allowing it to turn and be taken out with little difficulty. A small thermometer K L is inserted into the pillar of the stand. The manner of using the instrument is this:—After having driven all the ether into the ball B by the heat of the hand, it is to be placed at an open window, or out of doors, with the ball B so situated as that the surface of the liquid may be upon a level with the eye of the observer. A little ether is then to be dropped upon the covered ball; evaporation immediately takes place, which, producing cold upon the ball A, causes a rapid and continuous condensation of the ethereal vapour in the interior of the instrument. The consequent evaporation from the included ether produces a depression of temperature in the ball B, the degree of which is measured by the thermometer D. This action is almost instantaneous, and the thermometer begins to fall in two seconds after the ether has been dropped. A depression of 30 or 40 degrees is easily produced, and the ether has been seen to boil, and the thermometer driven down below 0° of Fahrenheit's scale. The artificial cold thus produced, causes a condensation of the atmospheric vapour upon the ball B, which first makes its appearance in a thin ring of dew, coincident with the surface of the ether.

The degree at which this takes place is to be carefully noted. A little practice may be necessary, to seize the exact moment of the first deposition; but certainty is very soon acquired. It is advisable, when the instrument has been constructed with a transparent ball, to have some dark object behind it, such as a house, or a tree; as the cloud is not so readily perceived against the open horizon. The depression of temperature is first produced at the surface of the liquid, where evaporation takes place; and the currents, which immediately ensue to effect an equilibrium, are very perceptible. The bulb of the thermometer D is not quite immersed in the ether, that the line of greatest cold may pass through it. In very damp or windy weather the ether should be very slowly dropped upon the ball, otherwise the descent of the thermometer will be so rapid as to render it extremely difficult to be certain of the degree. In dry weather, on the contrary, the ball requires to be well wetted more than once, to produce the requisite degree of cold. If at any time there should be reason to suspect the accuracy of an observation, it may easily be corrected by observing the temperature at which the dew upon the glass again disappears: the mean of the two observations (whose errors, if any, will lie in contrary directions) will give the true result. It is obvious that care should be taken not to permit the breath to affect the glass. With these precautions the observation is simple, expeditious, easy, and certain.

Anemoscopes.

Under this name are comprehended numerous inventions for measuring the strength and velocity of the wind, as the Wind-gage of Dr. Lind, Kirwan's Anemometer, Bouguer's Wind-gage, Dr. Brewster's Anemometer, Professor Leslie's Anemometer, &c.

The Wind-gage of Bouguer is an ingenious contrivance, and consists of a hollow tube, A A, B B, fig. 6, in which a spiral spring, C D, is fixed, that may be more or less compressed by a rod, F S D, passing through a hole within the tube at A A. Then having observed to what degree different forces or given weights are capable of compressing the spiral, mark divisions on the rod in such a manner, that the mark at S may indicate the weight requisite to force the spring into the situation, C D: afterwards join at right angles to this rod at F, a plane surface, C F E, of any given area at pleasure; then let this instrument be opposed to the wind, so that it may strike the surface perpendicularly, or parallel to the rod; then will the mark at S show the weight to which the force of the wind is equivalent.

Fig. 7 is a representation of an Anemometer constructed by Dr. Brewster of Edinburgh; it indicates the force of the wind in compressing a column in a glass tube. The metal cap A B, (fig. 7,) bent at a right angle, is fixed upon the top of the glass tube B C, which communicates at C with another glass tube, D E, of a much smaller bore, with a bulb, E, at its end. Some mercury or other liquid is poured into the tube B C, and of course rises to the same level, *m*, *n*, in both tubes. When the mouth A is exposed to the wind, the liquid at *m* descends in the tube, and by rising in the stem D E, compresses the enclosed air till there is an equilibrium between the elasticity of the air and the force of the wind. To prevent the fluid from oscillating, a thin disk of wood floats on its surface at *m*. The scale of this instrument, to ensure accuracy, should be formed by actual experiment.

Fig. 8 is a representation of an ingenious instrument invented by Professor Leslie, and to which he has given the name of *Æthrioscope.* This instrument appears to be a delicate modification of Mr. Leslie's differential thermometer, and its use is to measure those frigorific impressions which are produced by slight variations in distant parts of the atmosphere. The upper ball, as shown in the figure, is about half an inch in diameter, and the lower one, at the bottom of the scale, is about four fifths of an inch. The tube, which does not exceed four inches in length, has its bore contracted a little above its junction, with the short cylindrical cavity that holds the coloured liquor: by this simple contrivance the capillary action of the tube is greatly increased; the descent of the column into the ball by any sudden change of temperature prevented; while the motion of the fluid is retarded, without affecting the accuracy of its play.

We would conclude this interesting subject with a quotation from the excellent treatise on Electricity by the late Mr. Singer, an author whose name will be respected as long as science is cultivated.

After some very judicious remarks on the subject of Meteorology, he thus concludes:—

Speculations of this kind are only useful as a stimulus to inquiry, and should therefore be always regarded with caution, and offered with diffidence: they are indeed more favourable to the progress of true knowledge, when proposed as questions for experiment to resolve, than when expanded into hypotheses for experiment to confirm. For it is an impolitic excitement of false confidence, to erect a massive superstructure on a basis of doubtful stability.

Although the immediate causes by which the various phenomena of the atmosphere are produced are still far beyond our comprehension; yet the connexion of their several effects is a sufficient demonstration that they are not purely mechanical, but subservient to the direction of supreme power and intelligence. By this means the most simple arrangement becomes the source of sublime effects. The process of evaporation, which modifies the action of the sun's rays, and conveys to every part of the earth's surface a source of fertility, at the same time diversifies the appearance of the atmosphere by an endless variety of imagery, enlivens the horizon with the most brilliant and glowing tints, and probably effects those electrical changes, which are the precursors of the most magnificent phenomena in nature.

CHAPTER XV.

ASTRONOMY.

This branch of science is so named from two Greek words, viz. αϛηρ a *star*, and νομος *law* or rule. Astronomy is the most sublime, useful, and interesting of all the sciences cultivated by man, and treats of the heavenly bodies and their various phenomena.

By some the term is extended to the theory of the universe, with the primary laws of nature; but, properly speaking, astronomy is a mixed mathematical science, by which we become acquainted with the magnitudes, motions, periods, distances, eclipses, &c. of the celestial luminaries.

Astronomy is unquestionably a science of very great antiquity, and, indeed, must have been coeval with the human race, since we cannot suppose that the exhibition of the Divine glory, which is afforded by the heavenly bodies, could fail to attract the attention, and excite the curiosity of those who first beheld it. It is, however, quite uncertain, in what age or country the united observations of many were so far methodized as to raise astronomy to the dignity of a science, and conjectures on the subject would be vain.

Those who have written on the history of astronomy seem agreed that the foundation for a regular system of this science was laid by Hipparchus, who flourished at Alexandria about 162 years before Christ. This philosopher, who was a native of Bithynia, determined the length of the tropical year with unprecedented accuracy; his result not varying more than 4½ minutes from the truth.

In the sixteenth century astronomy began to assume a more rational appearance from the introduction of the system of Copernicus, published at Nuremberg, and afterwards perfected by Kepler and Galileo.

The antient philosophers, Pythagoras excepted, entertained the idea of the immobility of the earth. This system, called the Ptolemaic system, from Ptolemy, an Egyptian astronomer, places the earth in the centre, and the other planets round about her in the following order: viz. the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn, beyond which were situated the fixed stars.

This system, which is replete with difficulties, gave way to that which is commonly known by the name of the Copernican system, from the inventor Nicholas Copernicus. This philosopher, with the view of obviating the difficulties of preceding systems, admitted the motion of the earth on her own axis, and also her motion in the ecliptic round the sun. This system met with much opposition; and for maintaining it, Galileo was thrown into the prison of the Inquisition, and purchased his liberty by a recantation of the alleged heresy.

But however accordant with the principles of reason and common sense the system of Copernicus was, it met with a powerful opposition for a time from Tycho Brahe.

From observing that a stone thrown from the top of a lofty tower fell at its base, Tycho supposed that the earth must be without motion; not being aware that the same thing would happen on board a ship sailing at a swift rate, where, if a stone be dropped from the mast head, it will fall at the foot of the mast, provided the motion of the vessel be neither accelerated nor retarded during the time of falling.

This new system, which exceeded the Ptolemaic in confusion and difficulty, died with its projector, and the Copernican system is now universally received.

OF THE APPARENT MOTION OF THE HEAVENLY BODIES.

When we cast our eyes towards the heavens, we perceive a vast concave hemisphere at an unknown distance, of which the eye seems to constitute the centre. The earth stretches at our feet like an immense plain, and appears to meet and to bound the heavenly hemisphere. The circle around where the earth and heavens seem to meet and touch each other is called the horizon. It is natural to imagine, that besides the hemisphere which we perceive, there is another, exactly similar, concealed from our view by the earth, and that the earth therefore is suspended in the middle of this heavenly sphere, with all its inhabitants. A little observation turns this suspicion into certainty; for in a clear evening the heavenly hemisphere is seen studded with stars, and its appearance is changing every instant. New stars are continually rising in the east, while others are setting in the west. Those stars, that early in the evening are seen just above the eastern horizon, will at midnight be seen in the middle of the starry hemisphere, and may be traced moving gradually towards the west, till at length they sink below the horizon. If we look to the north, we perceive that many stars in that quarter never set at all, but move round and round, describing a complete circle in 24 hours: these describe their circles round a fixed point in the heavens, and the circles diminish more and more the nearer the star is to that point. This fixed point is called the north pole. There must be a similar fixed point in the southern hemisphere, called the south pole. In this way the heavenly sphere appears to turn round two fixed points, called the poles, once in every 24 hours. The imaginary line which joins the points is called the axis of the world.

We shall illustrate this by a diagram. Let HO, plate XVIII. fig. 1. represent the circle of the horizon seen edgeways, when it appears as a straight line; let HPFORQ be the complete sphere of the heavens, of which let HPEO be the visible hemisphere, and HQRO the in visible; then will P be the pole of the former, and R the pole of the latter, and the line P R the axis of the sphere. Draw the line QE through the centre of the sphere C, and it will represent the edge of a great circle equally distant from both poles, and at right angles to the axis; this is called the *equator*, because it divides the heavens into two equal parts. If HO be the horizon, the highest point, or that over our heads, as M, is called the zenith; and the opposite one N, the nadir.

The sun rises in the east, ascends to the highest point in the arch, which he describes, and descends in the west. The highest point to which he ascends is called the mid-day point; through which, and the zenith, if a great circle is drawn, it is called a meridian of the place; and all the stars cross this circle or meridian twice in twenty-four hours, but those which go below the horizon are seen only to cross it once. The three great circles in the heavens are, the horizon, the equator, and the meridian. The first determines the rising and setting of the heavenly bodies; and also their altitude, for which last purpose we must suppose another great circle to pass through the star and the zenith, called a vertical circle, upon which we reckon the number of degrees the star is from the horizon. The quadrant is an instrument used to ascertain this altitude. The three great circles above mentioned form the basis of all observations on the heavenly bodies; and, therefore, it is necessary to determine their relative situations. Had the polar star been exactly at the pole, nothing more need be done than to obtain the altitude of this star for that of the pole; but as it is two degrees from the pole, that number must be added to this altitude to find that of the pole.

The elevation of the pole being found, it is easy to find that of the equator: thus HMO, or the visible part of the heavens, contains 180 deg.; but it is 90 deg. from the pole P to E the equator: now if PE be taken from the semicircle HMO, there remain 90 deg. for the other two arcs; or, the elevation of the pole and equator are together equal to 90 deg.; so that the one being known and subtracted from 90 deg. it will give the other, consequently, the elevation of the pole, at any place, is the complement of the elevation of the equator, and the elevation of the equator is equal to the distance from the pole to the zenith.

The sun does not always rise at the same point; for in the beginning of March he appears to rise more to the north every day, to continue longer above the horizon, and to be higher at mid-day. Thus he continues till towards the end of June, when he retrogrades in the same order till near the end of December, when he begins to move forward as before. This change in the sun's place occasions the difference in the length of the days and nights, and the vicissitudes of the seasons.

The ecliptic is that path or great circle which the sun is supposed to complete in a year. It differs in situation from the equator; for the sun rises above the equator in summer, and not so high in winter. The points of the ecliptic where the sun is when at the greatest distance from the equator are called solstitial points; and the distance between the equator and ecliptic, at those points, is named the obliquity of the ecliptic, which is nearly 23 deg. 30 min.

The equinoctial colure is the great circle which passes at right angles to the equator, through the two points of it intersected by the ecliptic, and called the equinoctial points. The solstitial colure is the other great circle at right angles to the equator, and passes through the poles of the ecliptic.

Lesser circles of the sphere, touching the solstitial points, and at right angles to the axis, as AC, BD, are called tropics: that on the north side of the equator is denominated the tropic of Cancer; and that on the south, the tropic of Capricorn. The two polar circles FG, IK, are 23 deg. 30 min. distant from the poles.

The zodiac is a broad portion of the heavens, extending about eight degrees on each side of the ecliptic; it is divided into twelve parts, called signs; and each sign into thirty parts or degrees. Circles of celestial longitude are great circles of the sphere, standing at right angles to the plane of the ecliptic, dividing the same into equal parts. Upon the ecliptic is reckoned the longitude of any fixed star, from the point where the ecliptic and equator intersect each other in the vernal equinox, called the first point of Aries, and the arch of any of these circles intercepted between a star and the ecliptic, is the latitude of that star. The equator is divided into degrees, called degrees of right ascension, and from the equator to the poles the degrees of declination are counted on the meridian of the place.

OF THE SOLAR SYSTEM.

If we examine the heavens in a clear night, we shall find that the greater of the stars keep the same place with respect to each other; that is, if we observe two stars having a certain apparent distance from one another one night, they will be found to maintain the same distance every succeeding night: these are therefore denominated fixed stars.

But there are others which change their places with regard to the fixed stars, and also to one another. These were formerly five; but Dr. Herschell has discovered a sixth, which he has named Georgium Sidus, though foreign astronomers give it the name of the person who discovered it. Four others that have been since discovered by Piazzi, Olbers, and Harding are admitted into the system under the names of Ceres, Pallas, Juno, and Vesta. All these are denominated planets, from the word *plano*, to err or wander. The sun and moon, the bodies with which we are particularly concerned, appear to us the largest of all the heavenly bodies; yet we do not from their apparent, determine their real magnitudes. At the same time it is certainly of great importance to have some idea of the method by which astronomers form an estimate of the apparent magnitude of those bodies. From the established principles of optics we know that all bodies are rendered visible by means of the luminous rays which they transmit to us. Thus, for example, when we observe a celestial body, the rays of light which proceed from the opposite sides of its disc intersect in our eye a certain angle; and the arc which measures that angle determines the apparent diameter of the object. The fixed stars, however, do not present a disc so regular as to enable us by the eye, or even by the aid of the best instruments, to determine exactly their diameters. It is, however, to be observed that they constantly retain the same mutual arrangement and position, rising and setting constantly on the same points of the horizon, at least with hardly any perceptible variation, except after long intervals of time.

The ten planets, above mentioned, and of which we shall afterwards speak more fully, are exceptions to these rules. These do, indeed, rise and set in the same manner as the fixed stars rise and set; but if we carefully mark their positions, we shall perceive, after the lapse of a few days, that they have changed their places; they neither accompany the same stars, nor do they rise and set on the same points of the horizon.

If we suppose the plane of the earth's orbit which passes through the centre of the sun to be extended in every direction as far as the fixed stars, it will describe a great circle, or the ecliptic, with which the situations of the orbits of the other planets are compared.

The planes of the orbits of all the other planets must pass through the centre of the sun; but if extended as far as the fixed stars, they form different circles from each other and from the ecliptic; one part of each orbit being on the north, and the other on the south side of the ecliptic. Therefore the orbit of each planet cuts the ecliptic in two opposite points called the nodes of the planet. That where the planet passes from the south to the north of the ecliptic is called the ascending node, and the other the descending node. The angle which the plane of a planet's orbit makes with the plane of the ecliptic is called the inclination of the planet's orbit.

The two points in a planet's orbit farthest from, and nearest to, the body round which it moves, are called the apsides; the former of which is usually named the aphelion, and the lower, the perihelion: the diameter joining these points is called the line of apsides. When the sun and moon are nearest the earth they are said to be in perigee, and when farthest from it to be in apogee.

When a planet is between the sun and the earth, or the sun is between it and the earth, then the planet is said to be in conjunction with the sun; and when the earth is between a planet and the sun, that planet is said to be in opposition. When a planet comes between the earth and the sun, it appears to pass over the disc or surface of the latter, and this is called the transit of the planet.

When a planet moves from west to east, it is said to have direct motion, or to be in consequentia; and when from east to west, to have retrograde motion, or in antecedentia. The heliocentric place of a planet is the place which it appears to be in if viewed from the sun; and the place it occupies when viewed from the earth is termed its geocentric place.

The planets do not move with equal velocity in all parts of their orbits, but move faster when nearest to the sun, and slower in the remotest parts; and if a straight line is drawn from the planet to the sun, and this line is supposed to be carried along by the periodical motion of the planet, then the areas described by this line, and the path of the planet, are proportioned to the times of the planet's motion.

The planets perform their periodical revolutions in different times, but the cubes of their mean distances are as the squares of their periodical times.

The sun forms the centre of attraction round which all the planets move. These have also the property of attracting each other, which occasions some irregularity in their motions. This mutual attraction between the planets and the sun keeps them from flying off from their orbits by the centrifugal force, which is generated by their revolving in a curve; and this force again keeps them from falling into the sun, which would be the case, if it were not for the motion impressed upon them. Thus these two powers balance each other, and preserve the order of the system.

This doctrine, which is founded on the demonstrations of Sir Isaac Newton, may be thus illustrated:

If a planet at B, fig. 2. gravitates, or is attracted towards the sun, S, so as to fall from B to *y*, in the time that the projectile force would have carried it from B to X, it will describe the curve BY by the combined action of these two forces, in the same time that the projectile force, singly, would have carried it from B to X, or the gravitating power, singly, have caused it to descend from B to *y*; and these two forces being duly proportioned, the planet obeying them both will move in the circle BYTV. But if, whilst the projectile force would carry the planet from B to *b*, the sun's attraction should bring it down from B to I, the gravitating power would then be too strong for the projectile force, and would cause the planet to describe the curve BC. When the planet comes to C, the gravitating power (which always increases as the square of the distance from the sun, S, diminishes) will be yet stronger for the projectile force, and by conspiring, in some degree, therewith, will accelerate the planet's motion all the way from C to K, causing it to describe the arcs BC, CD, DE, EF, &c. all in equal times. Having its motion thus accelerated, it thereby acquires so much centrifugal force, or tendency to fly off at K, in the line K *k*, as overcomes the sun's attraction; and the centrifugal force being too great to allow the planet to be brought nearer to the sun, or even to move round him in the circle *k l m n*, &c. it goes off, and ascends in the curve KLMN, &c. its motion decreasing as gradually from K to B as it increased from B to K, because the sun's attraction now acts against the planet's projectile motion just as much as it acted with it before. When the planet has got round to B, its projectile force is as much diminished from its mean state as it was augmented at K; and thus the sun's attraction being more than sufficient to keep the planet from going off at B, it describes the same orbit over again by virtue of the same forces or powers. A double projectile force will always balance a quadruple power of gravity. Let the planet at B have twice as great an impulse from thence towards X as it had before; that is, the same length of time that it was projected from B to *b*, as in the last example; let it now be projected from B to *c*, and it will require 4 times as much gravity to retain it in its orbit; that is, it must fall as far from B to 4 in the time that the projectile force would carry it from B to C, otherwise it would not describe the curve BD, as is evident from the figure. But in as much time as the planet moves from B to C, in the higher part of its orbit, it moves from I to K, or from K to L, in the lower part thereof; because from the joint action of these two forces, it must always describe equal areas in equal times throughout its annual course. These areas are represented by the triangles BSC, CSD, DSE, ESF, &c. whose contents are equal to one another from the properties of the ellipses.

OF THE SUN.

The first thing that strikes the mind when contemplating this glorious orb is, its astonishing magnitude. This vast globe is found to be about 880,000 miles in diameter, and, consequently, contains a mass of matter equal to *thirteen hundred thousand globes* of the size of the earth. Were its central parts placed adjacent to the surface of the earth, its circumference would reach two hundred thousand miles beyond the moon's orbit, on every side, filling a cubical space of 681,472,000,000,000,000 miles. If it would require 18,000 years to traverse every square mile on the earth's surface, at the rate of 30 miles a day, it would require more than *two thousand millions of years* to pass over every part of the sun's surface, at the same rate. Even at the rate of 90 miles a day, it would require 800 years to go round its circumference. Of a body so vast in its dimensions, the human mind, with all its efforts, can form no adequate conception. It appears an extended universe in itself; and although no other body existed within the range of infinite space, this globe alone would afford a powerful demonstration of the Omnipotence of the Creator.

Though the sun seems to perform a daily circuit around our globe, he may be said, in this respect, to be fixed and immoveable. This motion is not *real*, but only *apparent*, and is owing to the globe on which we are placed moving round its axis from west to east; just as the objects on the bank of a river seem to move in a contrary direction when we are sailing along its stream in a steam boat. The only motion which is found to exist in the sun is a motion of *rotation*, like that of a globe or ball twirled round a pivot or axis, which is performed in the space of 25 days and 10 hours. This motion has been ascertained by means of a variety of dark spots which are discovered by the telescope on the sun's disk; which first appear on his eastern limb, and after a period of about thirteen days, disappear on his western, and, after a similar period, re-appear on his eastern edge. These spots are various, both in number, in magnitude, and in shape; sometimes 40 or 50, and sometimes only one or two are visible, and at other times the sun appears entirely without spots. Most of them have a very dark nucleus, or central part, surrounded by an umbra, or a fainter shade. Some of the spots are as large as would cover the whole continent of Europe, Asia, and Africa, others have been observed of the size of the whole surface of the earth; and one was seen, in the year 1779, which was computed to be more than *fifty thousand miles* in diameter.—With regard to the nature of this globe, it appears highly probable, from the observations of Dr. Herschel, that the sun is a solid and opaque body, surrounded with luminous clouds which float in the solar atmosphere, and that the dark nucleus of the spots is the opaque body of the sun appearing through occasional openings in this atmosphere.

The following are Sir Isaac Newton's observations on the sun. 1. That its heat is seven times greater in Mercury than with us, and that water there would be all carried off in steam. 2. That the quantity of matter in the sun is to that of Jupiter as 1100 to 1, and that the distance of Jupiter from the sun is in the same ratio to the sun's diameter; consequently the centre of gravity of the sun and Jupiter is nearly in the superficies of the former. 3. That the quantity of matter in the sun is to that of Saturn as 2360 to 1, and the distance of Saturn from the sun is in a ratio little less than that of the sun's semi-diameter, whence the common centre of gravity of Saturn and the sun is a little within the latter. 4. Therefore the common centre of gravity of all the planets cannot be more than the length of the solar diameter from the centre of the sun. 5. The sun's diameter is equal to 100 diameters of the earth, and the whole body exceeds that of the earth a million of times. 6. If 360 degrees are divided by the quantity of the solar year, it gives 59′ 1″, and the horary motion is 2′ 27″.

OF THE PLANETS.

There are two kinds of planets, primary and secondary. The first move round the sun, and respect him only as the centre of their motions. The secondary planets, called also satellites or moons, are smaller planets, revolving round the primary, while they, with the primary planets about which they move, are carried round the sun. The planets move round the sun at various distances, some being much nearer to him than our earth, and others being much farther off. There are 11 primary planets, which are situated with respect to their distances from the sun as follows: Mercuy ☿, Venus ♀, the Earth ⊕, Mars ♂, Ceres, Pallas, Juno, Vesta, Jupiter ♃, Saturn ♄, and the Herschel planet, or the Georgium Sidus ♅. Of these our earth is accompanied by one moon, Jupiter has four moons, Saturn has seven moons, and the Herschel planet has six moons. None of these moons, except our own, can be seen without a good telescope. The other five planets do not appear to have any satellites or moons. All the planets move round the sun from west to east, and in the same direction do the moons revolve round their primaries, excepting those of the Herschel planet, which seem to move in a contrary direction. The paths in which they move round the sun are called their orbits. These orbits are elliptical; but the eccentricity of the ellipses is so small, that they approach very nearly to circles. They perform their revolutions also in very different periods of time. The time of performing their revolutions is called their year. The planets are evidently opaque bodies, and they shine only by reflecting the light which they receive from the sun; for Mercury and Venus, when viewed by a telescope, often appear to be only partly illuminated, and have the appearance of our moon when she is cusped or horned, having the illumined part always turned towards the sun. From the appearance of the boundary of light and shadow upon their surfaces, we conclude that they are spherical; which is confirmed by some of them having been found to turn periodically on their axes. Venus and Mercury being nearer to the sun than our earth, are called inferior planets, and all the rest, which are without the earth's orbit, are called superior planets.

Mercury. ☿

Mercury, the planet nearest the sun, is about thirty-seven millions of miles distant from the sun, and revolves around him in 88 days. His diameter is about 3200 miles. Before the discovery of the four new planets, Ceres, Pallas, Juno, and Vesta, in the beginning of the present century, this globe was considered as the smallest primary planet in the system. His surface, however, contains above thirty-two millions of square miles, which is not much less than all the habitable parts of our globe. On account of his nearness to the sun, he is seldom seen by the naked eye; being always near that quarter of the heavens where the sun appears; and therefore few discoveries have been made on his surface by the telescope. M. Schroeter concludes, from certain observations, that this planet revolves round its axis in 24h. 5′.

The sun will appear to an inhabitant of Mercury seven times larger than to an inhabitant of the earth; and if the degree of heat be in proportion to a planet's distance from the sun, the heat in this planet will be seven times greater than on the surface of our globe; and consequently, were the earth placed in the same position, all the water on its surface would boil, and soon be turned into vapour.

Venus. ♀

Venus, the next planet above Mercury, is computed o be sixty-eight millions of miles from the sun, and by moving at the rate of seventy-six thousand miles an hour, she completes her annual revolution in 224d. 16h. 49′ 11½″ and her synodical revolution is about 548 days. Her diameter is seven thousand seven hundred miles, or nearly the size of our earth, and herdiurnal rotation on her axis is preformed in 23h. 21′ 7″.

Venus is often seen by the unassisted eye in broad day-light. The proportion of light and heat received by this planet from the sun is 1·91 times greater than the earth, and it is surrounded with an atmosphere the refractive powers of which differ very little from ours.

Like Mercury, it sometimes passes over the sun's face, and its transit has been applied to one of the most important problems in astronomy, as by it the true distances of the planets from the sun have been determined. These transits take place in the months of June and December. The first will be on the 8th December, 1874.

When Venus is to the west of the sun, it rises before the sun, and is called a morning star; this appearance continues about 290 days together: when this planet is to the east of the sun, it sets after the sun, and is called an evening star for about the same period of 290 days. Venus appears the brightest of the planets: it has a considerable atmosphere, and some astronomers assert that they have discovered mountains on its surface.

The Earth. ⊕

The earth which we inhabit is the planet next in order; hence we say Mercury and Venus are inferior, but all the planets which are further from the sun than the earth is are superior planets. The earth is eighty two millions of miles from the sun; it performs its sidereal revolution in 365d. 6h. 9′ 11·5″; and it passes from one solstice to the same again in 365 d. 5 h. 49 m.

That our planet is a globular body is easily proved. Mariners, when they leave land, first begin to lose sight of the lower parts, and so on gradually of the higher; and persons on shore first see the tops of the masts, before the ships themselves appear. Now, if the earth were a perfect plane, all parts would be seen at once. The earth is not, however, a perfect sphere, but a spheroid, having its equatorial diameter longer than the polar, or the axis. The diameter at the equator is 7977 miles, and at the poles 7940 miles. The earth has two motions; a diurnal, on its own axis, in twenty-four hours, and an annual motion round the sun as above stated. The first motion occasions light and darkness, day and night.

The natural days are not equal; for a natural day is the time wherein the earth performs one revolution round its axis, and such a portion of the second revolution as is equal to the space which the sun has apparently gone that day; but these spaces are unequal, therefore the additional portion of the second revolution will be at times greater or less, consequently the natural days must be unequal. Hence arises the difference between a sun-dial and a time-piece, the former measuring the length of a natural day, and the latter dividing time into equal portions of twelve hours each; the clock will be before the dial when the natural day is more than twenty-four hours, and after it when less.

The *equation* of time is the difference between the mean length of the natural day and that of a day measured by the sun's apparent motion, or between *mean* and *apparent* time. The hour by apparent time being known, to find what is the true time, add the equation to apparent time, if the day, by the clock, is shorter than by the dial; and subtract it when longer.

The causes of the difference between mean and apparent time are, 1. The obliquity of the ecliptic with regard to the equator; 2. The unequal motion of the earth in an elliptical orbit.

The heavenly bodies appear higher than they really are, owing to the refraction of the rays of light by our atmosphere; so that to bring the apparent to the true altitudes, the quantity of refraction must be subtracted according to a table which may be found in all books of elemental astronomy.

The twilight is also owing to this refraction of the rays, which, being bent by the atmosphere, visit the earth before the sun actually rises, and keep him in view after he is set.

Mars. ♂

Mars, first above the earth's orbit, is easily known by his red and fiery appearance. He performs his sidereal revolution in 686d. 23h. 30′ 39″ or in 1·881 Julian years; and his mean synodical revolution is about 780 days or in about 2·135 years.

His mean distance from the sun is above one hundred and forty-two millions of miles.

The rotation on his axis is performed in 1d. 39′ 21·3″; and his mean diameter is 4398 miles, or rather more than one half the size of our earth.

This planet has a very dense but moderate atmosphere, and he is not attended by any satellite. And the proportion of light and heat received by him from the sun is ·43, that received by the earth being considered as unity.

Mars changes his phases, in the same manner as the moon does from her first to her third quarter, according to his various positions with respect to the earth and sun.

Jupiter. ♃

Jupiter is, next to Venus, the most brilliant of all the planets, whom he sometimes, however, surpasses in brightness. He performs his sidereal revolution in 4332d. 14h. 18′ 41″, or in 11·862 Julian years. But this period is subject to some inequalities. He performs his mean synodical revolution in about 399 days.

His mean distance from the sun is above four hundred and eighty-five millions of miles.

The rotation on its axis is performed in 9h. 55′ 49·7″; and its axis forms an angle of 86° 54′ 30″, with the plane of the ecliptic.

His mean diameter is equal to 91522 miles: consequently he is about 11½ times as large as our earth. The axis of his poles is to his equatorial diameter as ·9287 to 1, or as 13 to 14.

The proportion of light and heat received from the sun is ·037, that received by the earth being considered as unity.

He is surrounded by faint substances called zones or belts, which are supposed to be parts of his atmosphere, and is accompanied by four satellites.

Saturn. ♄

Saturn can hardly be seen by the naked eye. When examined by a telescope, it exhibits a very remarkable appearance. It is surrounded by a thin, flat, broad luminous ring, which surrounds the body of the planet, but does not touch it. This ring casts a strong shadow upon the planet, and is divided into two, by a distinct line in the middle of its breadth. The rings are circular, but appear elliptical from being viewed obliquely.

According to Dr. Herschel, the dimensions of the rings, and the space between, are as follows:

	Miles.
Inner diameter of the smaller ring	146,345
Outside diameter of ditto	184,393
Inner diameter of the larger ring	190,248
Outside diameter of ditto	204,883
Breadth of the inner ring	20,000
Ditto of the outer ring	7,200
Ditto of vacant space	2,839

Besides this ring, Saturn has seven moons of different sizes, and its body is surrounded also by belts, like those of Jupiter. See Fig. 3.

Georgium Sidus. ♅

This planet was discovered by Dr. Herschel, March 13th, 1781, who gave it the name which it now bears. It performs its sidereal revolution in 30,688d. 17h. 6′ 16·2″, or in about 84 Julian years: and it is probably situated at the confines of the planetary system.

Its distance from the sun is upwards of eighteen hundred millions of miles; and its apparent diameter is scarcely 3·9″.

Six satellites accompany this planet; which move in orbits nearly perpendicular to the plane of the elliptic.

Vesta. ⚶

The next planet in our system is Vesta, for the knowledge of which we are indebted to Dr. Olbers of Bremen, being first discovered by him March 29th, 1807. Its distance from the sun is about two hundred and twenty-three millions of miles, and its annual revolution in its orbit is performed in 3 years 7½ months. But neither has its diameter, nor the duration of diurnal rotation, been yet ascertained.

Ceres. ⚳

Ceres is the next higher planet, in our system; which was first discovered by Piazzi, of Palermo, Jan. 1st, 1801. Its mean distance is nearly the same as that of Pallas, and consequently its annual revolution is performed in nearly the same time.

Juno. ⚵

Juno, the next in order, is another new planet; discovered by Mr. Harding, at the observatory at Lilienthal, near Bremen, Sept. 1st, 1804. The mean distance of this planet from the sun is estimated at two hundred and fifty-three millions of miles, and its annual revolution is performed in 4 years, 4 months, and

6 days; but its diameter, and the time of its revolving on its axis, are unknown.

Pallas. ⚴

The next superior planet above Juno is Pallas, which was first observed by Dr. Olbers, March 8th, 1812: the mean distance of which from the sun is reckoned to be about two hundred and sixty-three millions of miles, and its revolution in its orbit is made in about 4 years, 7 months, and 10 days; but, like the two former, its diameter and diurnal rotation have not as yet been correctly ascertained.

OF COMETS.

Besides these planets already mentioned, there are some other bodies which revolve round the sun, called comets. They move in very eccentric ellipses, and their periods of revolution are so long, and so uncertainly known, that few are ever observed twice. They are only seen by us when they are in that part of their orbit which is nearest to the sun, and when they move so fast, that they soon become again invisible to us. The number of comets is unknown; numbers of small ones have been discovered by telescopes. Their distances are inconceivably great, and most of them move entirely beyond the planetary orbits; though some have descended below Mars. Their appearances are very different. Some appear only a faint vapour; others have a nucleus or solid part in the middle. When they approach the sun, they put forth the appearance of a beard or tail of luminous matter, which is sometimes of astonishing length. These tails are always directed from the sun. There are three comets, viz. of 1680, 1744, and 1759, which require particular notice. The comet of 1680 was remarkable for its near approach to the sun; so near, that in its perihelion it was not above a sixth part of the diameter of the luminary from the surface thereof. The tail, like that of other comets, increased in length and brightness as it came nearer to the sun; and grew shorter and fainter as it went farther from him and from the earth, till that and the comet were too far off to be any longer visible. The comet of 1744 was first seen at Lausanne in Switzerland, December 13, 1743, N. S. From that time it increased in brightness and magnitude as it was coming nearer to the sun. Its diameter, when at the distance of the sun from us, measured about one minute, which brings it out equal to three times the diameter of the earth. It came so near Mercury, that if its attraction had been proportionable to its magnitude, it was thought probable it would have disturbed the motion of that planet. Mr. Betts of Oxford, however, from some observations made there, and at Lord Macclesfield's observatory at Sherburn, found, that when the comet was at its least distance from Mercury, and almost twice as near the sun as that planet was, it was still distant from him a fifth part of the distance of the sun from the earth, and could therefore have no effect upon the planet's motions. He judged the comet to be at least equal in magnitude to the earth. He says, that in the evening of January 23, this comet appeared exceedingly distinct and bright, and the diameter of its nucleus nearly equal to that of Jupiter. Its tail extended above 16 degrees from its body; and was in length, supposing the sun's parallax 10″, no less than thirty-three millions of miles. Dr. Bevis, in the month of May, 1744, made four observations of Mercury, and found the places of that planet, calculated from correct tables, differed so little from the places observed, as to show that the comet had no influence upon Mercury's motion. The nucleus, which had before been always round, on the 10th of February appeared oblong, in the direction of the tail, and seemed divided into two parts, by a black stroke in the middle. One of the parts had a sort of beard brighter than the tail; this beard was surrounded by two unequal dark strokes, that separated the beard from the hair of the comet. These odd phenomena disappeared the next day, and nothing was seen but irregular obscure spaces like smoke in the middle of the tail; and the head resumed its natural form. February 15, the tail was divided into two branches; the eastern part about seven or eight degrees long, the western 24. On the 23d, the tail began to be bent; it showed no tail till it was as near to the sun as the orbit of Mars; the tail grew longer as it approached nearer the sun; and at its greatest length was computed to equal a third part of the distance of the earth from the sun. The comet of 1759 did not make any considerable appearance by reason of the unfavourable situation of the earth at the time its tail might otherwise have been conspicuous; the comet being then too near the sun to be seen by us; but it deserves particular consideration, as it was the first that ever had its return foretold. With respect to the real nature and use of the comets in the system, we are entirely unacquainted.

A remarkably fine comet appeared in the end of the year 1811, and continued visible during the beginning of 1812, the chief particulars relating to which are the following.

1. *The planetary body in the head of the comet,* as seen with the naked eye, presented a luminous appearance not unlike a star; but within its densest light there was an extremely small bright point, entirely distinct from the surrounding glare, and which by geometrical calculation was found to be from 428 miles to one hundred and twenty thousand miles in diameter.

2. *The eccentricity, colour, and atmosphere of the planetary body.* The bright point was not in the middle of the head, but more or less eccentric at different times; and the colour of the planetary disc was of a pale, ruddy tint, like that of such equally small stars as are inclined to red; and Dr. Herschel infers that it was visible by rays emitted from its own body, yet that since the central illumination, which, moderately magnified, was pretty uniform, became diluted into a gradual decrease from the middle towards the outside, the comet was surrounded by a transparent and elastic atmosphere. And this atmosphere was more than five hundred and seven thousand miles in diameter.

3. *The tail of the comet.* The most brilliant phenomenon that accompanied the comet was the stream of light which we call the tail.

The greatest real length of the tail was one hundred millions of miles, and the real breadth was fifteen millions of miles. This tail had a curved shape or flexure, and in its general appearance it seemed to be inclosed at the sides by two streams or branches arising from the sides of the head. And the tail of the comet being, on Nov. 9, very near the milky way, the appearance of the one compared to that of the other, in places where no stars could be seen in the milky way, was perfectly alike. And that the tail is a hollow cone we may infer from the fact that the inside showed a comparative darkness; whereas had it been a cone of solid luminous matter, the brilliancy would have increased toward the centre instead of diminishing.

OF THE MOON.

The moon is the constant attendant of the earth, and revolves around it in 27 days, 8 hours, but the period from one new or full moon to another is about 29 days, 12 hours. She is the nearest of all the heavenly bodies; being only about two hundred and forty thousand miles distant from the earth. She is much smaller than the earth; being only about 2180 miles in diameter.

The surface of the moon when viewed with a telescope presents an interesting and a variegated aspect; being diversified with mountains, valleys, rocks, and plains, in every variety of form and position. Some of these mountains form long and elevated ridges, resembling the chains of the Alps and the Andes; while a variety of others, of a conical form, rise to a great height, from the middle of level plains, somewhat resembling the Peak of Teneriff. But the most singular feature of the moon is, those circular ridges and cavities which diversify every portion of her surface. A range of mountains of a circular form, rising three or four miles above the level of the adjacent districts, surrounds, like a mighty rampart, an extensive plain; and, in the middle of this plain or cavity, an insulated conical hill rises to a considerable elevation. Several scores of these circular plains, most of which are considerably below the level of the surrounding country, may be perceived with a good telescope, on every region of the lunar surface.

The phases of the moon, as they appear at eight different points of her orbit, are represented by fig. 4. where S represents the sun, T the earth, and ABCD, &c. the moon's orbit. When the moon is at A, in conjunction with the sun S, her dark side being entirely towards the earth, she will be invisible, as at *a*, and is then called the new moon. When she comes to her first octant at B, a quarter of her enlightened hemisphere will be turned towards the earth, and she will then appear horned, as at *b*. When she has run through the quarter of her orbit, and arrived at C, she shows us the half of her enlightened hemisphere as at *c*, when it is said she is one half full. At D she is in her second octant, and, by showing us more of her enlightened hemisphere than at C, she appears gibbous as at *d*. At her opposition at E, her whole enlightened side is turned towards the earth, when she appears round, as at *e*, and she is said to be full; having increased all the way round from A to E. On the other side she decreases again all the way from E to A; thus, in her third octant at F, part of her dark side being turned towards the earth, she again appears gibbous, as at *f*. At G she appears still farther decreased, showing again exactly one half of her illuminated side, as at *g*. But when she comes to her fourth octant at H, she presents only a quarter of her enlightened hemisphere, and again appears horned, as at *h*. And at A, having now completed her course, she again disappears, and becomes a new moon again, as at first.

OF THE SEASONS.

These are occasioned by the annual motion of the earth. The better to understand this, it must be considered that the axis of the earth is inclined to the plane of its orbit, about 23d. 30m. and it always keeps parallel to itself, or is directed constantly to the same point of the heavens.

Let fig. 5. represent the earth in different parts of its elliptic orbit. In the spring, the circle which separates the light from the dark side of the globe, called the terminator, passes through the poles *n*, *s*, as appears in the position A. The earth then, in its diurnal rotation about its axis, has every part of its surface as long in light as in shade; therefore the days are equal to the nights all over the world; the sun being at that time vertical to the equatorial parts of the earth. As the earth proceeds in its orbit, and comes into the position B, the sun becomes vertical to those parts of the earth under the tropic, and the inhabitants of the northern hemisphere will enjoy summer on account of the solar rays falling more perpendicularly upon them; they will also have their days longer than their nights, in proportion as they are more distant from the equator; and those within the polar circle, as will be perceived by the figure, will have constant day-light. At the same time the inhabitants of the southern hemisphere have winter, their days being shorter than their nights, in proportion as they are farther from the equator; and the inhabitants of the polar regions will have constant night. The earth then continues its course to the position C, when the terminator again passes through the poles, and the days and nights are equal. After this the earth advances to the position D, at which time the inhabitants of the northern hemisphere have winter, and their days are shorter than their nights. The positions B and D are the solstitial points, and A and C the equinoctial points; they are not equidistant from each other, because the sun is not in the centre, but in the focus of the ellipsis. In summer, when the earth is at B, the sun is farther from it than in winter, when the earth is at D, and, in fact, the diameter of the sun appears longer in the winter than in summer. The difference of heat is not owing to the sun's being nearer to us, or more remote, but to the degree of obliquity with which its rays strike any part of the earth.

OF THE SATELLITES.

As the satellites uniformly describe orbits nearly with their respective primaries, at the centre or focus, they are most probably moved by a similar force to that which moves the planets round the sun, consequently they must describe the areas of their orbits proportional to the times: and their mean distances from the centres of the primaries must be the cube-roots of the squares of the times of their revolutions.

The time of a synodic revolution of a satellite may be thus found: observe when the primary planet is in opposition to the passage of the satellite over its body, and mark the time when it is half-way between the two opposite edges of the planet's disc, for then it will be nearly in conjunction with the centre of the planet, and also in conjunction with the sun. After some time, observe when the primary is in opposition, and the satellite in conjunction with its centre, and divide the intervening period between the two observations, by the number of conjunctions of the sun, in that space, which will give the time of a synodic revolution. Another method is by means of the eclipses of the satellites: observe when the satellite enters the shadow of its primary, called its immersion, or when it comes out of the shadow, called its emersion; and after some time repeat the same observation when an eclipse again occurs, and from the interval of these times, and the number of eclipses in that interval, the mean time of a synodic revolution will be had by division.

The distance of a satellite from its primary may be found by means of its greatest elongation, as seen from the earth. Another method is, by measuring with a micrometer, at the time of the satellite's elongation, its distance from the centre of the planet, also the semi-diameter of the planet, the distance being in the same terms as the semi-diameter. Or when the periodic times of all the satellites are known, and the mean distance of one of them, the mean distances of the others may be found from the proportion between the squares of the periodic times and the cubes of the distances.

OF ECLIPSES.

When any of the heavenly bodies is obscured or darkened by the shadow of another falling upon it, or by the interposition of any body, it is said to be eclipsed. Eclipses were formerly viewed as ominous, but the improvements of science have clearly proved that they have no connexion with future events; but that they depend entirely upon regular and invariable causes, and may be calculated and foretold with the greatest certainty. As the earth is an opaque body, enlightened only by the sun, it will cast a shadow towards that side which is farthest from the sun. As the sun is much larger than the earth, the shadow of the latter must be conical, or end in a point, as in fig. 6.

On the sides of this conical shadow, there is a diverging shadow, the density of which decreases in proportion as it recedes from the sides of the former conical shadow: this is called the penumbra. As the moon revolves round the earth sufficiently near to pass through the shadow of the earth, an eclipse must always take place when these three are all in one straight line. An eclipse of the moon can never happen but at the time of full moon; but on account of the inclination of the moon's orbit to that of the earth, an eclipse cannot take place every full moon. When the moon passes entirely through the earth's shadow, the eclipse is total; but when only part of it passes through the shadow, the eclipse is partial. The quantity of the moon's disc which is eclipsed (and the same thing is to be understood of that of the sun in a solar eclipse) is expressed by twelve parts, called digits, that is, the disc is supposed to be divided by twelve parallel lines; then, if half the disc is eclipsed, the quantity of the eclipse is said to be six digits. When the diameter of the shadow, through which the moon must pass, is greater than the diameter of the moon, the quantity of the eclipse is said to be more than twelve digits; thus, if the diameter of the moon be to that of the shadow as four to five, then the eclipse is said to be fifteen digits. The duration of a lunar eclipse is various; it sometimes lasts two or three hours. The eclipses of the sun are owing to a different cause from those of the moon. They are occasioned by the moon's coming directly between us and the sun, and therefore obstructing our view of it. When the moon happens to be in conjunction with the sun, or between the sun and the earth, viz. at the time of the new moons, the shadow of the moon falls upon the surface of the earth; hence, properly speaking, such eclipses should be called eclipses of the earth. But the whole disc of the earth cannot be involved in the shadow of the moon, because the moon is much smaller than the earth, and the shadow of the moon is conical. Thus, in fig. 7. the rays of the sun, S, being intercepted by the moon, L, form the conical shadow CDG, which, falling upon the surface of the earth, entirely deprives that portion of it, upon which it falls, of the sun's light, and of course the inhabitants of that part of the earth will have a total eclipse of the sun. Beyond the dense conical shadow CDG there is a diverging half shadow, or penumbra CDEF, which is occasioned by the moon's intercepting only a part of the sun's rays from those places which fall within this penumbral cone, and are out of the dense shadow. Thus from the part of the earth Z, the portion YYB of the sun only can be seen; consequently the inhabitants of that part will have a partial eclipse.

As the moon is not always at the same distance from the earth, it sometimes happens that the conical dense shadow does not reach the earth, as in fig. 8. and only the penumbral shadow falls upon it; the eclipse consequently is partial to every part of the earth. Those who are at the centre of the penumbra will lose sight of the centre of the sun, by the interposition of the moon's body, which subtending a smaller angle than the sun, will not entirely cover its surface, so that there will be a ring of light all around. The eclipse is then said to be annular.

Seven is the greatest number of eclipses that can happen in a year, and two the least: if there are seven, five must be of the sun and two of the moon; if there are only two, they must be both of the sun; for in every year there are at least two eclipses of the sun. There can never be more than three eclipses of the moon in a year, and in some years there are none.

Though the number of solar eclipses is greater than of the lunar, in the ratio of 3 to 2, yet more lunar than solar eclipses are visible in any particular place, because a lunar eclipse is visible to an entire hemisphere, and a solar one only to a small part of it.

It is the lot of few persons to witness central eclipses, so that they may be considered as rare phenomena; nevertheless there are 28 such eclipses in each cycle of eighteen years, but the space over which every one of them appears to be central, is but a very confined tract. A beautiful phenomenon of this kind occurred to the inhabitants of London, in April, 1715, which is described by Dr. Halley. The darkness for a short time was so entire, that the stars became visible. Though the disc of the sun was wholly covered by the moon, a luminous ring of a faint pearly light surrounded the body of the moon, the breadth of which was about the tenth of the moon's diameter. In no part of this country did the obscuration last more than 3 minutes 57 seconds.

The satellites, or moons, of Jupiter, Saturn, and the Georgium Sidus, are often eclipsed by the planets to which they belong. The eclipses of Jupiter's moons are of much importance in astronomy and navigation; and observed with great attention, as being extremely useful in ascertaining the longitude.

When any of the planetary bodies disappear by another, or by the moon coming before it, it is called an occultation. The occultations of the fixed stars by the moon are likewise of great use in determining the longitudes of places.

OF THE FIXED STARS.

These are so called, on account of their not changing their places as the planets do. They appear of various magnitudes: but, for convenience, astronomers class them into six or seven divisions. To the naked eye they seem to be innumerable; but this is a deception occasioned, probably, by the refraction of our atmosphere.

The ancients divided the stars into several constellations, or systems; to distinguish which, they gave them names according to their fancies. To these have been added several others by modern observers.

Those stars which are not included in any constellation are denominated unformed. Besides the names of the constellations, the ancient Greeks gave particular appellations to some single stars, or small groups of them: thus, those in the neck of the Bull were called Pleiades; five in the Bull's face, Hyades; a bright star in the breast of Leo, the Lion's Heart; and one between the knees of Bootes, Arcturus.

Greek letters have been added by Bayera to stars in the several constellations of his catalogue (α being affixed to the largest star), by means of which any star may be easily found.

Twelve of the constellations lie upon the ecliptic, including a space about 16 degrees in breadth, called the zodiac, within which all the planets move. The constellations as far as the triangle, with Coma Berenices, are northern, those after Pisces southern. The distances of the fixed stars from us cannot be ascertained, therefore they must shine by their own light as our sun does, whence it is inferred that they are suns to systems similar to ours. Some of the larger stars have not the same situations observed by ancient astronomers; and new stars have appeared, while others, formerly described, are no longer seen. Some stars have a periodical increase and decrease; and many of the fixed stars, upon examination by the telescope, are found to consist of two.

Besides the phenomena already mentioned, there are many nebulæ, or parts of the heavens, which are brighter than the rest. The most remarkable of these is a broad irregular zone or belt, called the milky-way. There are others much smaller, and some so small that they can be seen only by telescopes. If the telescope be directed to these nebulæ, they are resolvable into clusters of stars, which appear as white clouds in instruments of less power. Dr. Herschel has rendered it highly probable, both from observation and well-grounded conjecture, that the starry heaven is replete with these nebulæ or systems of stars, and that the milky-way is that particular nebula in which our sun is placed. Reasoning analogically from the circumstances with which we are acquainted, we may infer, that the universe consists of nebulæ or distinct systems of stars; that each nebula is composed of a prodigious number of suns or bodies that shine by their own native splendour; and that each individual sun is destined to give light to numbers of worlds that revolve about it. What an august, what an amazing conception does this give of the works of the Creator! Instead of one world and one sun, we find thousands and thousands of suns, ranged around us at immense distances, all attended by innumerable worlds, all in rapid motion, yet calm, regular, and harmonious, invariably keeping the paths prescribed them; and these worlds peopled with myriads of intelligent beings, formed for endless progression in perfection and felicity.

OF THE TIDES.

The ocean covers more than half the globe; and this large body of water is in continual motion, ebbing and flowing alternately; that is, if the tide is now at high water mark, it will presently subside, and flow back for about six hours, when it will be at low water mark: the time of high water, however, is not always the same, but is about three-quarters of an hour later every day, for near thirty days, when it begins as before.

For example: suppose at a certain place, it is high water at three o'clock in the afternoon on the day of new moon, the next day it will be high water at three-quarters of an hour after three, the day following at half-past four, and so on till the next new moon, when it will be again high water at three. This answers to the motion of the moon; for she rises every day about three-quarters of an hour later than the preceding one; and thus completes her revolution round the earth in about thirty days.

According to the Newtonian principle of attraction, these phenomena are thus explained.

The waters at Z on the side of the earth next the moon, M, fig. 9. are more attracted than the central parts O by the moon, and these again more than the waters on the opposite side at N; therefore the distance between the earth's centre and the waters on its surface under and opposite the moon will be increased. To explain this more particularly, though the earth's diameter bears a considerable proportion to its distance from the moon, yet this diameter is nothing when compared to the earth's distance from the sun, consequently the difference of the sun's attraction on the sides of the earth opposite to him will be far less than the difference of the moon's attraction on the sides opposite to her; therefore the moon must raise the tides higher than they could be by the sun. Sir Isaac Newton has determined that the influence of the sun in this case is three times less than that of the moon. The tides, then, are properly the joint production of the sun and moon; or, in fact, there are two tides, a solar and a lunar, whose effects are joint or opposite according to the situation of the bodies by which they are affected. When the sun and moon act together, as at new and full moon, the flux and reflux become considerable; and are called spring tides. But when one tends to elevate the waters, and the other to depress them, as at the moon's first and third quarters, then the flux and reflux will be diminished; these are called neap tides.

The sun being farther from our hemisphere in March and September, than in February and October, is the cause why the greatest tides happen a little before the vernal, and a little after the autumnal equinox.

When the moon is in the equator, the tides are equally high in both parts of the lunar day, which is 24 hours 50 minutes; but as she declines towards either pole, the tides are alternately higher or lower in northern or southern latitudes. The tides are so retarded in their passage through channels, and so affected by capes and head-lands, as to happen variously at different places. The tide raised in the German Ocean, when the moon is three hours past the meridian, takes three hours to arrive at London Bridge. Lakes have no tides because every part is attracted alike. The Mediterranean and Baltic seas have but small elevations, on account of the narrowness of the inlets by which they communicate with the ocean.

The following tabular view of the Solar System is from Ferguson's Astronomy, by Dr. Brewster, second edition.

TABULAR VIEW OF THE SOLAR SYSTEM.

Names of the Planets.	Mean diameters in English miles.	Mean diameters from the sun, in round numbers of miles.	The correct mean distances, that of the earth being 100000.	Mean apparent diameters as seen from the earth.	Mean diameters as seen from the sun.	Densities, that of water being 1.	Proportional quantities of matter.	Diurnal rotations round their own axis.	Inclination of axis to orbits.	Inclination of orbits to the ecliptic in 1780.
The Sun	883246			32′ 1″.5		$1\frac{2}{15}$	333928	25^{d} 14^{h} 8′ 0″	82° 44′ 0″	
Mercury	3224	37,000,000	38710	10	16″	$9\frac{1}{6}$	0.1654	14 24 5 28	- - - -	7° 0′ 0″
Venus	7687	68,000,000	72333	58	30	$5\frac{11}{15}$	0.8899	0 23 21 8	- - - -	3 23 35
The Earth	7911.73	95,000,000	100000		17 .2		1	1 0 0 0	66 32 0	0 0 0
The Moon	2180	95,000,000	100000	31 8	4 .6	$4\frac{1}{2}$	0.025	29 17 44 3	88 17 0	5 9 3 at a mean.
Mars	4189	144,000,000	152369	27	10	$3\frac{2}{7}$	0 0875	0 24 39 22	59 22 0	1 51 0
Ceres	163 1024	263,000,000	276500	1 6 .4	- -	2	- -	- - - - - -	- - - -	10 37 0 in 1804.
Pallas	80 2099	265,000,000	279100	0 .5 6 .5	- -	2	- -	- - - - - -	- - - -	34 50 40 in 1804.
Juno	1425	252,000,000	265700	3	- -	- -	- -	27 hours probably.	- - - -	21 0 13 4 in 1804.
Vesta	238	225, 000, 000	237300	0 5	- -	- -	- -	- - - - - -	- - - -	7 8 46 in 1809.
Jupiter	89170	490,000,000	520279	39	37	$1\frac{1}{24}$	312.1	0 9 55 37	90 nearly.	1 18 50 in 1780.
Saturn	79042	900,000,000	954072	18	16	$0\frac{18}{32}$	97.76	0 10 16 2	60 probably.	2 20 50 in 1780.
Georgium Sidus	35112	1,800,000,000	1908352	3 54	4	$0\frac{99}{100}$	16.84	- - - - - -	- - - - -	0 46 20 in 1780

To the student who is desirous of prosecuting this interesting subject, a careful perusal of the work from which the preceding table is copied is earnestly recommended, not only for the simplicity of the text, but also for the valuable supplement of the editor, which contains a full and comprehensive detail of all the modern discoveries in astronomy, with an ample description of astronomical apparatus, and the most approved method of using it.

CHAPTER XVI.

PHYSIOLOGY.

We have now gone through the leading branches of science, and directed the attention of the student to what we conceive to be the most important and efficient course of study which he can pursue, if, in scientific matters, he would become a practical man, and not remain a mere theorist. It may, perhaps, be expected that, before closing the volume, we should give some directions as to the best method of conducting a course of scientific experiments; but as this may very easily be inferred from the explanations that have already been given, and as it would involve numerous and very unnecessary repetitions, we shall devote the few remaining pages to the subject of Physiology, a subject without some notice of which no work of this description can be considered as complete.

Hitherto we have merely noticed some of the most striking properties of matter, and the changes which the skill of the philosopher causes it to undergo. Or if we have even gone a few steps beyond this, and contemplated the mineral and vegetable kingdoms; or raising our eyes to the heavens, have beheld the sublime scenery there displayed to our astonished minds; still we have only beheld matter, of itself totally inert and dead, and although mysteriously operated on by an invisible and almighty agency, yet never destined to rise in the scale of existence, but to continue for ever in the same lowly sphere.

The case is otherwise when we come to contemplate *man*, that miracle of creation. He is not only placed at the head of all animated creation, but, taking into view his immortal destination, it may be affirmed that for him the UNIVERSE was brought into existence. It is not meant by this to be affirmed that man, as to his material part, is not entirely dependent on a foreign source for his existence: his life is constantly derived from the original source of all being; nor has he a single power which in this respect he can say is his own. The contemplation of such a being as man affords the most ample scope for the exercise of the highest powers with which we are endowed. Much has been written on the subject; and numerous, and various, and ingenious theories have from time to time appeared respecting the vital principle in general; but after all, how little is understood of the matter. We see in the vegetable kingdom a process going on by which certain portions of the elements in which a plant is placed are changed into bark, and leaves, and wood, &c.:—and in like manner in the animal kingdom we perceive the food received converted into bone, and muscle, and nerve, &c. That such a process is going on we can readily perceive, yet do we only behold the external operations of an internal and invisible agent, which can no more be comprehended by our limited faculties, than can HE from whom such agency proceeds. It is utterly in vain, therefore, that philosophers, in their speculations, contend with each other respecting the vital principle, and the nature and seat of the human soul. For, supposing that by a series of well-conducted experiments the physiologist should actually succeed in discovering the soul or spirit, and should exhibit it to our view in such a manner as would admit of the closest examination; still we should only perceive, and be enabled to examine, not any thing having *life in itself*, but a mere *recipient of life*;—a vessel, so to speak, which is momentarily supplied from the Great

Fountain of life, one of whose essential perfections is his being *invisible* to mortals.

It is not, however, our intention to occupy this chapter with speculations on this part of the subject; our attention must be chiefly confined to the material part of man, to that part which comes within the province of our very limited powers of observation; and of which it may with the strictest propriety be said that it is fearfully and wonderfully made, although doomed to return to its origin the earth.

Before entering on particulars, it may be useful here to make some general remarks on matter. It is freely owned that there is no small difficulty attends the investigation of this subject; and although it has engaged the attention of such men as Newton, Berkeley, Priestley, &c., we do not seem to be yet in possession of any satisfactory theory of it. The following extract from Tilloch's Philosophical Magazine appears to us decidedly superior to any thing on the subject that has yet fallen under our observation. After some preliminary observations, the intelligent writer of the article thus proceeds.

Bulk and extension pre-suppose solid elementary particles, of which forms are compounded; for if there be no such primary solid particles, there can be no material solidity whatever, either primary or derived; thus no material bulk or extension,—which is absurd.

A solid or primary particle of matter must be the smallest particle, and can admit of no divisibility; for if it can be divided into parts, it is not a solid or primary or the smallest particle; matter is not therefore infinitely divisible.

That original, elementary, or solid particle of matter, which admits of no further division, must be the smallest particle of matter; and to say that there is no such thing as this smallest particle, is the same as to affirm that there are no material forms at all;—because it is to affirm that a whole can exist without the parts necessary to compose it.

From this it follows, that there is but one elementary principle in matter, of which principle the primary particle above mentioned consists,—and that all material subjects are forms compounded by motion arranging and co-arranging this elementary principle in innumerable relations and modes; for if there be primary material particles, these must be innumerable, in order to their entering into and producing the innumerable forms and combinations of forms observable in the material universe. It is, moreover, in accordance with reason and observation, thus to consider the original substantiality of matter, whence arises our idea of a simple or primary particle of material substance, called an atom; a congregation of which atoms, by modes of motion, furnishes the idea of natural compounds, or material subjects as they exist in nature, in all their varieties; for as it is evident that modes of motion produce changes in material subjects by transforming them into other material subjects of a totally different form and quality, so analogy points to the conclusion,—that all differences in material subjects, as they exist in nature, are effects of motion disposing primary particles into forms, and then operating successive and various combinations of those forms; and thus, that what is called chemical action, is, when considered in its origin, nothing more than an effect of motion in the more refined and subtle order of substances;—decomposition being effected by opposing forces, composition by attractive forces; and thus also, chemical action, like that which is called mechanical, is resolvable into an effect of motion.

The primary particles of matter, or the substances of which the material universe is compounded, appear evidently to be passive, and to be operated upon by active substances of a higher order in creation: and that this is the case may be concluded from observing the various subjects in nature, to the life of which matter may be said to serve as a fixing or ultimate medium, or instrumental basis; for nothing of life appears to belong inherently to the material substances composing those forms or subjects in nature: on the contrary, the material substances composing such forms seem to contain and to be operated upon by *interior* forms of life, actuating and disposing them, by modes of motion, into outward forms corresponding to such *interior* or inward forms.

Matter, then, considered in itself, is a passive substance, created as an instrument, or medium, for the development of an active, living, immaterial substance, in the ultimate or lowest degree of existence, namely, in nature; and this by being made the passive subject into which such living and active subject may enter and manifest itself. Would not such a doctrine, if fully developed, satisfactorily explain some of the first principles of the economy of nature, and prove the presence of the invisible in the visible world, and the order of life therein? Under this view, the natural universe is primarily divisible into two *universals* or principles which enter into every particular of which it is constituted; namely, the active, immaterial, or spiritual; and the passive, material, or natural; the latter being created from, and for the use of the former, and being the last result of the Divine Operation.

To the above we add a remark or two, by another writer, which, although made upwards of twenty years ago, seem peculiarly appropriate to the existing state of matters on this subject, at least with some trifling allowances.

In consequence, he observes, of the radical change which has recently been effected in the whole body of chemical science, physiological researches have received a fresh impulse and a new direction. By modern chemistry many facts in the animal economy have been fully developed, which were before concealed. Such, however, is the proneness of mankind to extremes, that in this, as in other instances, the auxiliary has been made to usurp the rights of the principal; chemical affinity has been supposed fully explicative of living actions, and the idea of animation being regulated by a distinct principle ridiculed as visionary. We believe, however, the ridicule to have been misapplied; and we must still maintain that the attractions of matter, in the mode they contend for, are of a nature very different from those resulting from the agency of the life-producing powers on an organized body. For example: muscular contraction is generated by an abundant variety of external stimuli; among these, oxygen has been found to be one of the most active; the effect of the above agent has been therefore preposterously confounded with the agent itself, oxygen has been imagined to be the principle of irritability, and the development of life by consequence has been supposed immediately to result from its combination with the animal fibre: with equal justice might opium or any other stimulus be in this manner as it were vitalized.

It will readily be perceived from what we have advanced, that our opinions on the subject of physiology differ widely from those of some of the most eminent physiologists, British and foreign.

Among these we are sorry to rank the truly able and indefatigable Professor Lawrence; and more especially so because we think no writer on the subject has done more than he has done, both as it respects collecting appropriate materials; and judiciously arranging them. Mr. Lawrence has, most obviously, an extensive and experimental acquaintance with the human structure: he can describe its parts; show their connexion with and dependence on each other; explain the wonderful action of the innumerable parts which constitute this microcosm, with a fluency of speech and a degree of perspicuity which few can command; it is impossible to read him without at once comprehending his meaning; and yet we are now and then startled with sudden exhibitions of the veriest trifling, for which it seems almost impossible to account on any other principle than that of the weakest kind of prejudice prevailing over the best of sense.

Thus, for example, when he asks—"Where is the mind of the fœtus? where that of the child just born?" does not common sense inform him that it is in the fœtus, and in the child just born, but that it has not yet developed itself? But what better answer can we find to this question than is furnished in Mr. Lawrence's own words.

"Since we cannot go back to the first origin of living bodies, our only resource in investigating the true nature of the powers which animate them consists in examining their structure, and tracing the union of their elements. Our knowledge of these points is too imperfect for us to draw all the necessary inferences." Again, "This general and common *motion* of all parts *constitutes* the very essence of life, insomuch that parts separated from a living body immediately die, because they have no power of motion within themselves, and only participate in the general motion produced by the assemblage. Thus the peculiar mode of existence of any part of a living body arises from the whole; while in dead matter, each particle has it within itself. When this nature of life was once clearly recognized by the most constant of its effects, physiologists naturally attempted to discover its origin, and the mode of its communication to bodies which it animates. They looked at them in their earliest state, approaching as nearly as possible to the instant of their formation; but they could only discover them completely formed, and *already* possessing that circulatory motion, of which they were investigating the first cause.

"However delicate the parts of a fœtus or a vegetable, in the first moments that we can perceive them, they *still possess life,* and have within themselves the germ of all the phenomena which this life will develop in the sequel."

But let us for a moment examine Mr. Lawrence's own reply to the question which he puts with so much confidence. "Do we not," says he, "see it actually built up before our eyes by the action of the five external senses, and of the gradually developed internal faculties?"

Are we to understand from this that the five external senses acting in concert with the internal faculties actually produce what we denominate the soul or spirit of man? From the manner in which the doctor here and elsewhere expresses himself, one would suppose that he conceives these senses and faculties to exist prior to the soul, and the soul to be nothing more than the production of their joint operation. Do we not here plainly discover the old maxim, *nihil est in intellectu, quod non priuś fuit in sensu?* Most assuredly this is Mr. Lawrence's belief; and as the sentiment seems to be favourably received by many, we would, with all due deference to Mr. Lawrence, here warn the youthful reader against its atheistical tendency, and remind him that it is the perceptive faculty of the mind alone that gives to sense its name and nature; and that, therefore, after the separation of the soul from the body, the latter is destitute of sense. Nor do we deem it enough to admit that the life of the human soul is derived from God as a gift once given, and afterwards subsisting by itself, as a principle *detached from God,* and depending on other distinct causes for its continuation: no, we must also admit that it proceeds from God by *continual influx*, as light does from the sun, or as a stream from its fountain-head.

But Mr. Lawrence asks with an air of triumph "where shall we find proofs of the mind's independence on the bodily structure?" In answering this question, it may be right in the first place to inquire whether the Professor really ever met with an immaterialist who was foolish enough to affirm that the perceptions and thoughts of the mind enter it in a naked state, and not by means of organized forms?

There may be in the world men who would hazard such an affirmation; but before they could do so they must denounce as useless the whole of the wonderful mechanism of the human frame; and we are not afraid of contradiction when we say that Mr. Lawrence never met with such a character in the course of his life. Indeed in using such language he is evidently fighting with the creature of his own imagination. The reader, however, will better understand this part of the subject from the following remarks of an able writer in reply to one who denies the existence of any thing beyond mere matter.

"The light proper to the body is one thing; and the light proper to the soul, spirit, or mind of man, is altogether another. By spiritual light, which is truth, man discerns things spiritual or intellectual, and is enabled to examine, compare, and form a judgment upon civil, moral, and religious subjects; together with the relation they bear to each other, and the benefits arising from them to society. But by natural light, which proceeds from the sun, he can only discern natural objects, or such as present themselves before the sight of his natural eye; and even these he can have no perception of whatever, without the presence and aid of spiritual light, which gives him the capacity of beholding the external world through the instrumentality of the bodily eye, and its various configurations, according to the proximity or distance of the objects seen.

"Hence it is, that a living man, or one in whom the eye of the mind and the eye of the body act together as one joint power, is capable of perceiving natural objects; while a dead man, or rather a corpse from which the spirit is withdrawn, is utterly incapable of seeing or perceiving any-thing in nature, however perfect the organization or structure of the eye may be.

"A telescope is an instrument or medium of vision, whereby distant objects, like some of the heavenly bodies, otherwise invisible, are distinctly seen by the human eye. And again a microscope is an instrument or medium of vision, whereby objects too minute to be discerned by the naked eye are distinctly perceived. Yet no one will pretend to say, that the faculty of seeing is actually inherent in those instruments; but every one will readily admit, that it belongs to the person who uses either the one or the other. So in like manner the natural body is an instrument, medium, or organized form, by or through which the objects in nature, otherwise invisible, are distinctly seen by the human spirit; and therefore no one ought to presume, that man's faculty of seeing in reality belongs to the bodily eye; but every intelligent person will, in agreement with the truth, conclude, that it properly and strictly belongs to the spirit, which makes use of it as its instrument or organ of natural vision. In both cases the principal and the instrumental are distinct from each other; yet when the principal, which exists in a higher or more interior order of life, would extend its perception to a lower or more exterior state, it assumes to itself such a medium or instrument from this latter, as is best adapted to accomplish its design; and in such case the superior and the inferior, the principal and the instrumental, the observer and the telescope, the spirit and the body, act as one, or jointly together, in producing the effect. But who, besides an idiot, would ascribe to the instrumental medium and not to the principal agent, to matter and not to mind, to the mere body and not to the spirit, the distinguished prerogative of sight and intelligence?"—*Hindmarsh's Reply to Carlile.*

We should now proceed to give a brief sketch of the leading topics connected with this branch of science, but must first beg the reader's attention to the following truly beautiful passage, written, we believe, by Mr. Lawrence. "Of all the less general powers, which presuppose organization, but which do not seem to be necessary results of structure, those of sensation and voluntary motion are the most remarkable, and exert the greatest influence over the other functions. We are conscious of the existence of these powers in ourselves, and we attribute them, by an analogical mode of reasoning, to many other beings, which we therefore name animated beings, or animals. They seem to be necessarily connected together; for the idea of voluntary motion contains in itself that of sensation; since volition cannot be conceived without desire, and without a feeling of pleasure or pain.

"The goodness which we observe in all the works of nature will not allow us to believe that she has formed beings with the power of sensation, that is, with a susceptibility of pleasure and pain, without enabling them at the same time to approach to the one and fly from the other, at least to a certain degree. And if among the too real misfortunes which afflict our species, one of the most affecting is the sight of a man of sensibility deprived by superior force of the power of resisting oppression, the poetic fictions most apt to excite our pity are those which represent sensible beings inclosed in immoveable bodies; and the tears of Clorinda, flowing with her blood from the trunk of a cypress, ought to arrest the blows of the most savage man."

The above remarks are not less just than beautiful; and the reader will, we are convinced, be delighted with the following judicious observations from the same writer.

Independently of the chain, which unites these two powers, and of the double apparatus of organs which they require, they produce also several modifications in the faculties common to all organised bodies; and these modifications, joined to the two peculiar powers, constitute more particularly the essential nature of animals. Thus, in respect to nutrition, vegetables being attached to the earth, absorb nutritive fluids directly by their roots; these almost infinitely subdivided, penetrate the smallest intervals of the soil, and travel to a distance in quest of nourishment for the plant to which they belong; their action is quiet and constant, being liable to interruption only when drought deprives them of the necessary juices. Animals, on the contrary, fixed to no spot, but frequently changing their abode, required the power of transporting with them the provision of fluids necessary for their nutrition; they have therefore an interior cavity to receive their food; and on its inner surface there are the openings of absorbing vessels, which, to use the energetic language of Boerhaave, are real internal roots. The size of this cavity and of its orifices allowed in several animals the introduction of solid substances. These required instruments for their division, and liquors for their solution; in a word, nutrition was no longer performed by the immediate absorption of matters in the state in which the earth or atmosphere furnished them; it was necessarily preceded by various preparatory operations, which, taken altogether, constitute digestion.

Thus digestion is a function of a secondary class, peculiar to animals. Its existence, as well as that of the alimentary cavity in which it takes place, is rendered necessary by the power which animals have of voluntary motion; but it is not the only consequence of that power.

Vegetables, having few faculties, are simple in their organization; being composed almost entirely of parallel or slightly diverging fibres.

It was necessary that animals should have within themselves an active principle of motion for their nutritive fluid, not only because they were destined to constant changes of situation and temperature, but also from their more numerous and highly developed faculties requiring a much greater complication of organs. Hence the component parts became very intricate in their composition, and often very distant, and possessed in many instances a power of changing their relative position; consequently the means of carrying the nutritive fluid through such multiplied intricacies must be more powerful than in vegetables, and differently arranged. It is contained, in most animals, in innumerable canals, which branch out from two trunks, that communicate together in such a way, that the fluid urged into the branches of one is received by the roots of the other, and carried back to a common centre, from which it is propelled afresh.

At the point of communication between the two great trunks is placed the heart, whose contractions impel the nutritive fluid into all the branches of the arterial trunk; for the orifices of the heart possess valves disposed in such a way that the circulating juices can only move in the directions now described.

In this rotatory motion consists the circulation of the blood, which is another secondary function peculiar to animals, chiefly performed and regulated by the heart. This, however, is not so essentially connected to the faculties of sensation and motion as the business of digestion; for whole classes of animals (as insects) possess no circulation, and are nourished, like vegetables, by the mere imbibing of fluids prepared in the intestinal canal.

The blood seems to be merely a vehicle, receiving constantly from the intestines, skin, and lungs, different substances, which it incorporates intimately, and by which its losses arising from the preservation and growth of parts, are supplied. The nutrition of the body is performed during the course of the blood in the minute extremities of the arteries; here the fluid changes its nature and colour; and it is only by the addition of the various substances just pointed out, that the venous blood again becomes proper for the purposes of nutrition, or, in one word, again becomes arterial.

The venous blood receives the supplies furnished to it by the skin and alimentary canal, by a particular set of vessels, called lymphatics; in the same way it receives also the particles detached from various organs, in order to be sent out of the body by the different secretions.

The air entering the lungs seems to produce a sort of combustion in the venous blood, which is necessary for the support of life in all organized bodies. Vegetables, and such animals as have no circulation, respire (for that is the name given to this action of the atmosphere on the nutritive fluid) by their whole surface, or by means of particular vessels which convey air into the interior of the body. Those only, which enjoy "true circulation, breathe by means of a particular organ; because, in them, the blood constantly flowing to and from a common source, its vessels have been so arranged, that it is not distributed to the other parts of the body until after passing through the lungs; a circumstance which could not take place where the nutritive fluid is distributed uniformly through the body without being contained in vessels."

Of Sensibility and Contractility.

By means of the senses, and of the nerves which are continued from them to the brain, we perceive or feel the impression made on our bodies by external objects.

The brain, which is the true seat of this relative sensibility, being excited by these impressions, influences the moving powers of the muscles, and determines the exercise of their contractility. This property, subjected to the command of the will, is manifested by the sudden shortening of the muscular organ, which swells, becomes hard, and causes those parts of the skeleton to which it is attached to move. The nerves and the brain are the essential organs of these two properties; division of the former destroys sensation, and the voluntary motion of those parts to which the nerves are distributed.

But there is another kind of sensibility quite independent of the presence of nerves, existing in all organs, even where no nervous filaments are distributed. Bones, cartilages, ligaments, arteries, and veins, in short, all parts which are not influenced by the will, possess no nerves. Yet, though in their natural state they transmit to the brain no perceptible impression, though they may be injured without giving the animal any pain, and though the will has no influence over them, yet they enjoy a sensibility and contractility, by virtue of which they perceive impressions, and contract in their own manner, recognize in the fluids which circulate through them what is proper for their nutrition, and, separating this part, appropriate it to their own substance.

We recognize then in the parts of our body two modes of sensation, as well as two species of motion: a sensibility, by means of which certain parts transmit to the brain impressions which they feel, and of which we therefore become conscious; a second kind, pervading every part without exception, and presiding over the assimilating functions. We observe also two kinds of contractility corresponding to the differences of sensibility: the one by which the voluntary muscles perform the contractions determined by the action of the will; the other manifested by actions which are equally unknown as the causes which give rise to them.

Sensibility may then be either perceptive or latent. The former is attended with a consciousness of the impressions or perceptibility, and requires a peculiar apparatus. The latter, unaccompanied by consciousness, is common to every thing that lives; it has no particular organs, but is universally expanded in all living parts, whether of vegetables or animals.

Organic sensibility is merely the faculty of receiving an impression; animal sensibility is the same faculty, with the additional power of conveying it to a common centre. In the former case the effect terminates in the organ. The latter belongs only to animals, whose perfection is in a direct ratio to the quantity of this sensibility.

Of Digestion.

Digestion is a function common to all animals, by which foreign substances, introduced into their bodies, and submitted to the action of certain organs, change their qualities, and form a new compound fit for the purposes of nourishment and growth.

Animals alone are provided with digestive organs; all, from man to the polype, have an alimentary cavity, and its existence is, therefore, an essential character of animals. The loss which the body sustains in performing the various actions that take place in the living animal machine is supplied by means of the food. Hunger and thirst admonish us of the wants of our frame, and the pleasures of the palate are no less strong inducements to the procuring and taking of food.

The cause of hunger has been placed in the mutual attrition of the rugæ of the empty stomach; in the irritation produced by the gastric juice, &c. Perhaps it may be derived more justly from a sympathy between the stomach and the body at large. For when, in diseases of the pylorus, the food cannot be transmitted into the intestines, and does not therefore enter the system, great hunger is experienced, even although the stomach may be filled. Much depends on habit, and on the operations of mental causes: hunger is felt at the usual periods of our repasts; and, if it be not then removed by eating, will often cease spontaneously. The man of letters, absorbed in meditation, often forgets the natural wants of his body. Whatever diminishes the sensibility of the stomach makes hunger more tolerable. Thirst seems to consist more in a very troublesome dryness of the fauces and œsophagus, and in a peculiar irritation of these parts from the admixture of acrid and particularly saline matters with the food. The necessity of obeying both these calls varies according to the age, constitution, and particularly the habits of individuals: yet we may state, on the whole, that a healthy adult could not abstain from food for a whole day without bringing on considerable weakness; and that this abstinence could not be continued to the eighth day without the most imminent risk of life. Continued abstinence diminishes the weight of the body to a degree which becomes sensible in twenty-four hours, causes absorption of fat, great prostration of strength, increased sensibility with watchfulness, and a most painful dragging at the epigastric region. Hunger is more speedily fatal in proportion to the youth and strength of the individual. Thus, the wretched father whose dreadful history is immortalized by Dante, shut with his children in a dungeon, perished at last, on the eighth day of confinement, after witnessing the death of his four sons, amid the convulsions of rage and cries of despair. Although the admonitions of thirst are very imperious, yet drink does not seem so necessary to life and health as solid food. The mouse, quail, parrot, and several other warm-blooded animals never drink, and instances have been known in the human subject. Thirst always becomes greater when any watery secretions are much augmented, as in dropsy, and particularly in diabetes.

The food of man, and probably of every animal, is derived from organized matter. Nothing seems capable of furnishing nourishment that has not lived: the mineral kingdom, indeed, supplies some articles of seasoning, which are mixed with our food, and various medicines and poisons, which do not seem to be nutritious.

As man on the one hand is a most truly omnivorous animal, and capable of converting into nourishment almost every production of the animal and vegetable kingdoms, so on the other side he may continue strong and healthy although using one, and that a very simple kind of aliment. A woman, whose case is related in the Memoirs of the Medical Society of Edinburgh, lived on whey for fifty years. Many men live only on certain vegetables, as potatoes, chestnuts, dates, &c. Some wandering Moors, according to Adamson, live almost entirely on gum Senegal. Fish is the only food of numerous uncivilized tribes on different coasts; and flesh of others. Some barbarous hordes still eat raw meat, and even the human body sometimes serves them as a repast. In several islands between the tropics, particularly in the South Sea, there is no fresh water, and the milk of the cocoa-nut is used instead: various other singular facts relating to the food and drink of man might be collected here, showing very clearly that he is an omnivorous animal.

Whatever be the diversity of food, the action of the digestive organs always separates the same nutritive principle from it: in fact, let the diet be totally vegetable, or totally animal, the peculiar composition of our organs does not alter,—an evident proof that the matter we extract from aliment to appropriate to ourselves is always alike.

Of Absorption.

Absorption is that process by which the incessant waste of the system from the various secretions and excretions is constantly repaired. Thus after digestion has converted the aliment into chyle, this fluid is taken up by the lacteals or mesenteric absorbents, undergoes a farther preparation in these vessels, is thence conveyed to the thoracic duct, and at length enters the mass of circulating blood, to furnish the requisite secretions, excretions, and exhalations; in this manner a perpetual change is operated in the materials of which an animal body is composed, "for it should never be forgotten that organized living matter compounds and decompounds itself continually." But this composition and decomposition are perpetually under the influence of fibrous stimulation. "Each orifice of a lacteal and lymphatic, endued with a peculiar degree of susceptibility and power of contraction, dilates or contracts, absorbs or rejects, according to the mode in which it is affected by substances that are applied to it." Thus when the chyle is applied to the orifices of the lacteal vessels, it is not solely by means of capillary or any other species of attraction, that this fluid is made to enter its appropriate vessels, but such entrance is gained in virtue of the power possessed by chyle of stimulating these organs; a demonstration of which principle is furnished from those substances being rejected which, have not the power of producing that dilatation and contraction just spoken of.

Another curious fact in support of the principle that some substances are not capable of exciting the absorbent vessels, is furnished by those marks which seamen and others are accustomed to imprint on their skin. These are generally formed by first pricking holes in the cuticle, and then rubbing the part over with charcoal or gunpowder, substances which remain undissolved in the fluids, unabsorbed in the lymphatics, and therefore continue through life. Indeed solution is a necessary prelude to every case both of lymphatic and lacteal absorption. It is then by the peculiar action of the lymphatics on exhaled fluids, that lymph is formed; and of the lacteals on the chyle, that this last becomes animalized. Those glandular bodies which are observed in these vessels are supposed to have a very important influence on their contained fluids; and "although it is not known precisely in what these alterations consist of lymph and chyle, it may be said that the object of the glands seems to be, to occasion the most intimate mixture, the most perfect combination of elements; to impress a certain degree of animalization, as proved by the greater concrescibility of lymph taken from the vasa efferentio, or those which pass from glands; to deprive them of mere heterogeneous principles, or, at least, to alter them, that they may not become hurtful in passing into the mass of humours." Thus we find, that after absorption has been in the first instance effected by vital action, the contents of the absorbing vessels, still, however, under the same influencing principle, are the subjects of a species of animal chemistry.

Of the Circulation.

The circulation is the motion by which the blood, setting out from the heart, is constantly carried to all parts of the body in the arteries, and returns to the same point in the veins. The uses of this circulatory motion are, to submit the blood altered by the mixture of lymph and chyle to the contact of the atmosphere in the lungs, to convey it to several organs in which various animal fluids are separated from it, and to every part of the body, for supplying its growth and repairing its losses, by means of its nutritive particles when completely assimilated.

The word circulation, when used absolutely, comprehends the whole course of the blood, as well in the lungs as in the arteries and veins of the body at large. The greater circulation is the passage of the blood from the left side of the heart, through the arteries, to the extremities of the body, and its return through the veins to the right side of the same viscus. The lesser circulation is the transmission of the blood from the right to the left side of the heart, through the lungs.

The passage of the blood through the heart, *i. e.* from the right auricle to the left ventricle, by the medium of the lungs, is manifest from the structure of the heart itself. The valves, which are placed at its various apertures, will not admit of the blood's motion in any other direction than that which we have described. That this fluid passes from the heart into the trunk of the aorta, thence into its branches, and so on to the most minute ramifications, is evinced; 1. By the effect of ligatures on these vessels; the artery becomes turgid between the heart and the ligature, and empty between the ligature and its distribution. 2. By opening an artery when tied, above and below the ligature; the blood in this case flows from that opening only, which is nearest to the heart. 3. By ocular testimony; the passage of the blood can be seen with the aid of glasses in frogs, fishes, &c. The passage of the blood through the veins, in a contrary course to that in which it flows along the arteries, *i. e.* from the minute ramifications towards the trunks, and thence to the heart, is proved, 1. By the structure and disposition of the valves, which afford an invincible impediment to all retrograde motion. 2. By ligatures on these vessels, which make the vein turgid between the extremities of the body and the ligature, and empty in the rest of its course. 3. By opening a vein, when tied, above and below the ligature. 4. By microscopical observation in animals.

The passage of the blood from the arteries into the veins seems to flow as a corollary, from what we have stated concerning the proofs of its course in these two systems of vessels. We have shown that the ultimate arteries are continuous with the origins of the veins; that the blood moves from the heart to the extremities in the former vessels, and that it passes from the extremities to the heart in the latter. The intermediate passage is a direct consequence of these facts. But it may be demonstrated by direct proofs independently of this argument. If we tie the artery of a part, its correspondent vein receives no blood; if we take off the ligature, the vein is again filled. The quantity of blood expelled from the aortic ventricle is so considerable, that the supply can only be kept up by its return to the heart. We calculate that two ounces are sent into the aorta at each pulsation; if we suppose 80 pulsations in a minute, 9,600 ounces will be thrown out in an hour, and 14,400 pounds in a day. The same blood, therefore, which the aorta received from the heart, must be returned to this viscus; and the only passage, by which it can return, is through the veins. Lastly, the passage of the blood from the arteries into the veins may be proved by the direct testimony of the senses in living animals. The use of the microscope affords this proof in the transparent parts of cold-blooded animals, as the mesentery and web of the foot in frogs, the tail of fishes, &c.

Of Secretion.

The blood, circulated in the manner we have just mentioned, and prepared by the organs of respiration, is the source from which the various fluids of the animal body are formed in the process of secretion.

The various arrangements of these products are, in a great measure, arbitrary. Milk seems to be formed by the most easy process, as it resembles so strongly the nature of chyle. Next come the watery fluids; (so called from their appearance, although in composition they differ considerably from water, chiefly in containing albumen): the humours of the eye, the tears, sweat, lymph of the cellular substance, vapour of the thorax, abdomen, and pericardium, and the water of the ventricles belong to this class. The urine seems to come under the same head, although it is of a peculiar and compound nature; next follow the salivary and pancreatic juices; and then the mucous fluids poured into the alimentary, respiratory, and generative organs. The fat, marrow, grease of the skin, ear-wax, sebaceous matter of the eye-lids and of the external organs of generation in both sexes, constitute the class of adipous fluids. The liquor of the amnion, the synovia of the joints, and the prostatic fluid, are of a gelatinous kind.

These very various products are separated from the blood by very different organs. The most simple mode of secretion is that performed by the arteries of a part without any glandular apparatus; as the fluids of circumscribed cavities, the lymph of the cellular substance, and the fat and marrow.

Secretion is more complicated when performed by means of certain organs called glands. The most simple of these are the mucous follicles, found in various parts of the alimentary and respiratory canals; consisting of a small bag receiving the secreted fluid from the arteries, and expelling it through a short excretory duct. But the name of gland is applied more properly to the larger organs of complicated structure, as the pancreas, breast, salivary glands, &c. These, consisting of an aggregation of minute particles, are called conglomerate, to distinguish them from the lymphatic or conglobate glands. Each of them possesses an excretory duct, made up by the union of branches from the various component portions of the gland. The ultimate blood-vessels are arranged in very different ways in various glands; coiled up in roundish masses, as in the kidney, arranged like stars in the liver, and forming an appearance like a camel's hair pencil in the spleen.

How, or why, certain organs secrete certain liquors, is the most important and essential question in this subject; but one to which the present state of our knowledge does not enable us to furnish a satisfactory answer. Probably the chief and proximate cause consists in difference of structure, and perhaps in the arrangement of the minute vessels which are the organs of secretion. The peculiar powers of each part, its share of irritability and contractility, must also have an important influence. The mechanical explanation of the phenomenon by the straining of the fluids through pores of different sizes cannot be admitted for a moment. We have one fluid, the blood, sent into different organs; each of which separates from it a different produce of matter, differing, in many instances, from any contained before in the blood. Here there must be a decomposition and a recombination of elements produced by the living action of the gland.

Of Nutrition.

Digestion, by which the aliment received into the stomach is deprived of its nutritious particles; absorption, which conveys such nutritious portions into the fluids; and the circulation, by which it is further conveyed to the respective parts in order to undergo depuration by the various secretory organs; are all preliminary and subservient to the function now to be considered.

The indivisibility and individuality of the living body can only be maintained by an incessant change of the particles which enter its composition. "Thus the animal machine is continually destroyed, and at distant periods of life does not contain a single particle of the same constituent parts." The most commonly adduced evidence in favour of which, is the effect resulting from feeding animals with madder; for during the time that this substance is made part of the food, the bones become of a red colour, which is again lost if the madder is only for a short time suspended: proving that there is a constant decomposition and reformation even of those portions of the frame, which, from their compact texture, must be supposed the least susceptible of change. As then the parts of the body are constantly destroyed, new parts of the same nature are as constantly required, and to supply this demand is the office of nutrition. "A bone, for example, is a secretory organ that becomes incrusted with phosphate of lime: the lymphatic vessels, which in the work of nutrition perform the office of excretory ducts, remove this salt after it has remained a certain time in the areolæ of its texture. It is the same in muscles with respect to fibrine, and in the brain with albumen." We, therefore, find animal nutrition and organization, to consist in this; that the aliments having been converted first into chyle, and then into blood, and from this last having been furnished the various parts, solid and fluid, of which the animal is composed, such parts are at length separated by the peculiar action of their respective organs.

It has ever been the aim of the physiologist, more especially of recent times, to detect the prime, and in a manner, common principle subservient to nutrition, in order to estimate the proportionate quantity of nutrient matter furnished by different alimentary substances. We must, however, assiduously guard against that fallacy which would connect itself with our inferences from viewing the process of nutritive elimination as a process merely of chemistry. The separation and assimilation of nutritive matter may be pronounced to have greater reference to vital action than even to the substances themselves from which nutrition is extracted. For example: Let us suppose, with Dr. Cullen and many others, that the common principle drawn from alimentary matter is saccharine; let it even be demonstrated that such is the case; it by no means thence follows that the administration of saccharine matter in any form would be the means of conveying into the system the largest portion of nutrition.

Of Respiration.

The exposure of the blood to the atmospheric air, by which the chyle, that has entered the circulating system from the thoracic duct, is converted into blood, and by which those changes are effected in the whole mass of circulating fluid, which are essentially necessary to the continuation of life, takes place in the lungs.

The respiratory organ has been aptly compared to an empty bladder, placed in a pair of bellows, with its neck adapted to the instrument, and giving entrance to a column of air when the sides are separated. In breathing, the dilatation of the chest occasions the lungs to enlarge by the entrance of air into them from without; these viscera not possessing any means of enlargement in themselves: this is termed inspiration. The expulsion of the air, after it has served the purposes of respiration, by means of a process exactly contrary to the former, is called expiration. The diaphragm and the abdominal muscles are the chief agents in enlarging and diminishing the chest. The former muscle in its relaxed state is strongly arched, and the convexity of this arch is towards the chest. Its curved fibres become straight by the contraction: the whole muscle descends towards the abdomen, and pushes the abdominal viscera, which lie against its under or concave surface, downwards and forwards. Hence the surface of the belly rises when we draw air into the chest. In the next moment, the abdominal muscles contract and push back the viscera, and thereby diminish the chest in a degree proportionate to its former enlargement. The increase of the thorax, effected in this way, takes place in the perpendicular direction; but it may also be enlarged in its whole diameter by means of the intercostal muscles, which by elevating and twisting outwards all the ribs, push the sternum forwards, and enlarge the chest in every direction. When the action of these powers has ceased, the natural elasticity of the parts restores the parietes of the thorax to their former position. In natural respiration both these methods of altering the capacity of the chest are employed; but females seem to use the intercostal muscles more than the male subject, as the heaving of their bosom demonstrates; yet breathing can be carried on by either method, to the exclusion of the other; as we sometimes see under circumstances of accident or disease. In the case of a broken rib, where the rubbing of the broken ends would be highly painful, the chest is bound up so as to render the ribs motionless, and the diaphragm and abdominal muscles perform the whole business of respiration. When the diaphragm and abdominal muscles act together, they compress the viscera between them, and the pressure thus produced, assists in the expulsion of their contents. This effort is termed straining, and is seen in vomiting, and in the act of discharging the feces and urine.

The state of the mind considerably affects the mode of respiration, although the muscles of that function are so far independent of the will, that they act without any exertion of volition, and continue their functions during sleep, when all the voluntary powers are suspended. When the lover, plunged in a soft reverie, fetches a deep sigh, the physiologist observes a strong and protracted inspiration, followed by a similar expiration; crying and sobbing differ from sighing only in the circumstance of the expiration being interrupted, or divided into several distinct periods. In gaping, which is attended with a sense of weariness, there is a large inspiration, accomplished in a gradual manner, and by a kind of effort; the entrance of a great quantity of air is facilitated by opening the mouth wide: this is followed by a complete gradual expiration. Sneezing is a strong and violent expiration, and the noise accompanying it is produced by the air passing out with rapidity, and striking against the winding parietes of the nasal fossæ. The effort, which is occasioned by the irritation of the pituitary membrane, is a convulsive motion of the muscles of respiration, and particularly of the diaphragm.

In coughing the expirations are shorter and more frequent; the expelled air carries off the mucus lodged in the trachea and bronchiæ, and this discharge constitutes expectoration. Laughing is a short inspiration, followed by several short and rapid expirations.

The alternate dilatation and contraction of the chest proceed uninterruptedly from the moment of birth to the end of life; and in a healthy adult are repeated about fourteen times in a minute, so that each act of respiration corresponds pretty nearly to five pulsations of the heart.

In explaining the effect which the cessation of respiration produces, some have stated, that the lungs, being no longer distended by the air in inspiration, have their vessels folded, and consequently mechanically unfit for the circulation of blood through them. Bichat, in his excellent "Recherches sur la Vie et la Mort," has fully disproved this statement; and has shown, by incontrovertible experiments, that neither the empty state of the lungs in complete expiration, nor their distended condition in the most full inspiration, produces any obstacle to the passage of blood through the pulmonary vessels. He proves likewise, that when the cessation of the chemical phenomena of the lungs induces a cessation of the heart's action, this does not happen in consequence of the simple contact of black blood with the internal surface of the left ventricle; but in consequence of this blood, thus deprived of those principles which are necessary for maintaining the actions of parts, penetrating the tissue of the heart, and coming into contact with its fibres. The brain is affected in the same way, in consequence of the cessation of respiration; and the arrival of venous blood in this organ causes an immediate cessation of animal life, while the organic still subsists. The same blood too, accumulated in every other structure, probably affects the whole body with its mortiferous qualities; and consequently, a mechanical inflation of the lungs with pure air is the most powerful method of recovery that can be adopted in these cases.

OF SENSATION.

1. *Of Sight.*

The structure of the human eye, and the nature of vision, having been pretty fully described in the chapter on *Optics*, the reader is referred to the account there given.

2. *Of Hearing.*

The undulations of the atmosphere, excited by the vibrations of sonorous bodies, are collected in the external ear and auditory passage, as in a hearing trumpet, and are conveyed to the membrana tympani, which they cause to vibrate. The effect is transmitted through the small bones to the watery fluid that fills the internal ear, in which the delicate filaments of the auditory nerve float; and by this nerve the sensation is conveyed to the brain. Muscles attached to the small bones of the tympanum have the power of stretching or relaxing the membrane; and probably thereby adapt the organ to various quantities of sound, by diminishing acute, and augmenting the force of grave sounds, as the changes in the pupil of the eye accommodate that organ to a greater or less number of rays, according to the effect they produce.

An entire state of the membrana tympani is not essential to hearing; for the sense remains, where an opening has taken place in that part; yet it is necessary that the tympanum should communicate with the fauces, for an obstruction of the eustachian tube causes deafness.

Vibrations may be transmitted to the auditory nerves through the bones of the head; thus a watch placed between the teeth is heard very distinctly, although the ears are stopped, &c.

3. *Of Smelling.*

The cavity of the nose is divided into two parts, called the *nostrils,* by a partition, of which the upper part is bony, and the lower cartilaginous. The upper part of the cavity is covered with a thick glandulous membrane, above which the *olfactory nerve* is finely branched out and spread over the membrane of the spongy bones of the nose, and other sinuous cavities of the nostrils.

The odorous effluvia of bodies are disseminated in the atmosphere. The latter fluid passes through the nose in respiration, and thereby brings the odorous particles into contact with the olfactory nerves, which convey the impressions of odours to the brain. It is in the first pair of nerves only that the sense of smelling is supposed to reside, while the numerous twigs of the fifth pair that are distributed in the nose are merely for the purpose of general sensibility. Hence we see two very distinct modes of sensibility in this part, one of which may be entirely obliterated, while the other is augmented; in violent coryza the ordinary feeling is very acute, for the pituitary membrane is painful; but the person at the same time is not conscious of the strongest odours.

As air is the vehicle of odours, its passage through the nose, in ordinary respiration, is sufficient for the purpose of smelling; but when any odour is particularly agreeable, we make short and repeated inspirations, and at the same time shut the mouth, that the air which enters the lungs may pass entirely through the nose. On the contrary, we breathe by the mouth, or entirely suppress respiration, when odours are disagreeable to us.

4. *Of Taste.*

Every sense has been said to be strictly a modification of feeling; that of taste, however, approaches nearer than any other of the senses, even in its organization, to that of simple or proper feeling; the surface of the tongue, which is the principal residence of this perceptibility, only varying from the common integuments in being thinner, more vascular, and having cryptæ, or follicles, which secrete the mucus of the tongue. These are situated in greatest numbers near its tip, and are erected " when we masticate high-flavoured food, or have a strong desire for any savoury dish." " It is observed that the sense of taste in different animals is more perfect in proportion as the nerves of the tongue are larger, the skin finer and more moist, its texture flexible, surface extensive, motions more easy and varied. The sense of taste in man would, perhaps, be more delicate than that of any other animal, if he were not to blunt its sensibility early in life by strong drinks, spicy ragouts, and all the refinements of luxury that are daily invented."

The lingual branch of the fifth pair is considered as the true gustatory nerve, while those sent to the tongue by the eighth and ninth are regarded as merely nerves of motion. Although the tongue appears to be a single organ, it consists of two symmetrical halves; and should be considered as a distinct right and left organ closely applied to each other. This is shown in hemiplegia, where one-half only is paralysed.

5. Of Touching.

This has been with some propriety denominated the elementary sense, and all others considered as merely modifications, accommodated to certain properties of bodies. "Every thing that is not light, sound, odour, or savour, is appreciated by the touch." This sense resides throughout the whole extent of the nervous system; the peculiar organ, however, of touch, or that by which we come to a knowledge of the qualities of objects, is the cutis, spread over the external surface of the body. In some parts this sense is peculiarly modified; in the skin, for example, covering the apices of the fingers; and in such parts we meet with something resembling the papillæ on the tongue; but, perhaps, not exactly similar, as they are rather constituted of nervous projections, than of glandular cryptæ: they are surrounded by an extremely fine vascular membrane. When the sense of feeling is exercised, these papillæ are supposed to swell and elevate the epidermis, which in itself is totally insensible to all such stimuli as act exclusively on living fibre. The epidermis, like the nails and hair, which last proceed from it, is a mere defence of the body, unorganized, and consequently destitute of excitability.

Of the Brain and Nerves.

The organs of the animal functions, which keep up the connexion between the body and the faculties of the mind, and are therefore found only in animated organized bodies, may be conveniently divided into two classes; the sensorium, and the nerves; the latter including the nerves and their origins from the brain; the former comprehending the rest of the cerebral organ, by which the offices of the nerves are connected with the more noble part of our frame, the faculties of the mind; and which may therefore not unaptly be termed the organ of the mind; since it is *by* it that the mind combines and compares its perceptions, and draws inferences from them; in short, by which it reflects and thinks.

The brain, when brought into view by a removal of the cranium, presents a double motion; it rises slightly during expiration, and subsides again when the thorax is dilated. This is explained from the temporary obstruction which the return of the venous blood experiences when the lungs are compressed. But a more conspicuous elevation and depression of the cerebral surface arises from the impulse of blood into the arteries of the head; this motion is therefore perfectly synchronous with the pulse, and may be felt in every infant whose fontanelle is not closed. The quantity of blood received by the brain is very considerable; according to Haller's calculation, between two-thirds and a half of the whole mass of blood that enters the aorta. This blood is circulated through all the minute and numerous arterial ramifications of the pia mater, before it enters the brain, as it should seem, in order to diminish its impulsive force; it rises contrary to its gravity, and its conducting tubes have an angular and tortuous course before they branch out on the pia mater; which circumstances augment the retarding effect. Every thing, on the contrary, facilitates the blood's return, and prevents venous distension.

The vast and wonderfully complicated vascular apparatus of the brain, and the large proportion of blood sent to the organ, naturally lead us to expect, that this part and the heart are closely dependent on each other. If the cerebral arteries be all tied, the animal perishes instantly. The influence of the heart, essential to the preservation of life, does not seem to consist so much in the agitation which the cerebral arteries communicate to its substance, as in the effect which the arterial or oxygenized blood exerts on it. For if venous blood be sent into the head, instantaneous death ensues; and this seems to be the way in which the cessation of respiration, by drowning, hanging, &c. proves fatal.

Physiologists have endeavoured to trace the termination of nerves in the organs which they supply; but the research is almost too subtle for our imperfect modes of investigation. In some instances, as the optic and auditory, they are manifestly resolved into a soft pulp: and we conjecture by analogy, that the same mode may obtain in others.

That the sensible impressions made on our organs are conveyed by the nerves to the brain; and that the latter part is the seat of the sensation, although it is referred by the mind to the part itself; is proved by cutting or tying a nerve: in which case, the usual impression causes no perception. The truth of this assertion, which will hardly meet with credit among the uninformed, is illustrated by what happens to persons whose limbs have been amputated: they are constantly complaining of pains in the toes or fingers of the limbs they have lost. Here the middle of the nerve is irritated, but the pain is referred by the mind to its extremities.

That the nerves are the medium of connexion between the mind and its organs, is clear; but how their offices are performed is a much more obscure question. It has occupied the attention, and engaged the experiments of physiologists, in all ages; but nature has not hitherto lifted the veil, and the subject remains nearly in its original obscurity. An oscillatory or vibratory motion of the nerves, or a nervous fluid contained in or adhering to these organs, have been assumed in explanation of the facts. According to some, the latter is a liquid contained in tubes; while others liken it to caloric, light, oxygen, the electric or magnetic fluids.

The curious and complicated structure of the brain has led some to suppose, that particular powers resided in certain eminences or depressions of the brain; and this is the foundation of the peculiar notions of Dr. Gall, whose speculations have attracted so much notice. He contends, that the inequalities of the brain's surface are the seat of the mental powers, and of the various propensities, &c. of the human species; and that these are accompanied by corresponding irregularities of cernible by external inspection.

There are some other topics which might have been noticed before quitting this subject; but as our object has been throughout the volume to excite a desire for farther information on the subjects which it embraces, rather than to satiate the reader with any one of them, enough we trust has been said to render the book and its title consistent with each other.

THE END.

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